HARVARD ENGINEERING SCHOOL

HARVARD UNIVERSITY.

Bought
with an appropriation made by
the Corporation
for books in Engineering.

Received May 17, 1902.

$\underline{2}70$

HANDBOOK ON PETROLEUM

HANDBOOK ON PETROLEUM

FOR

INSPECTORS UNDER THE PETROLEUM ACTS

AND FOR THOSE ENGAGED IN THE STORAGE, TRANSPORT, DISTRIBUTION AND INDUSTRIAL USE OF PETROLEUM AND ITS PRODUCTS AND CALCIUM CARBIDE

WITH SUGGESTIONS ON THE CONSTRUCTION AND USE OF MINERAL OIL LAMPS

BY

CAPTAIN J. H. THOMSON

HIS MAJESTY'S CHIEF INSPECTOR OF EXPLOSIVES

AND

BOVERTON REDWOOD

ADVISER ON PETROLEUM TO THE HOME OFFICE

CONSULTING ADVISER TO THE CORPORATION OF LONDON UNDER THE PETROLEUM ACT

LONDON

CHARLES GRIFFIN AND CO. LIMITED

PHILADELPHIA : J. B. LIPPINCOTT COMPANY

1901

PREFACE.

The technology of petroleum has been already dealt with in considerable detail by one of us in a work issued by the same publishers in 1896, and the reception accorded to that work may be held to justify the belief that the author achieved the object he had in view.

In these circumstances it may be considered that ample information has been given on the subject, and it may therefore be well for us to state the grounds upon which we have been led to prepare this volume for the press.

In the work to which we have alluded an attempt was made to present a comprehensive historical, geographical and geological account of the great industry of which it treats, in the hope that such account would not only be of general interest, but would also prove to be of practical value to those occupied in the development of new oil fields. The methods employed in the producing of petroleum in the principal oil fields of the world, in refining the crude oil and in distributing the various commercial products, were also described at length, and a similar principle was adopted in dealing with the important subject of the testing of petroleum, the practices prevailing abroad as well

as in this country being indicated, and full particulars being given of a large number of instruments, of which many are of scientific rather than of practical interest or value.

A work which thus aimed at being encyclopædic in character was necessarily voluminous, although effort was made to condense it, and only a comparatively small number of the 873 pages which it contained could be devoted to those aspects of the subject which our attention has been directed to in writing this volume. Moreover, portions of the larger work were, also necessarily, written in highly technical language, requiring for its full comprehension some previous special knowledge, and these could only be of interest to a very limited number. It may further be pointed out that through the labours of the Select Committee on Petroleum which met during the Parliamentary Sessions 1896–7–8, a large amount of information, especially in regard to the use of mineral oil in lamps, has been placed at our disposal which was not available when the larger work was written, and that carbide of calcium, now largely used as a source of acetylene, has recently been placed under the Petroleum Acts.

In the present volume we have given only such particulars of the geographical and geological occurrence of petroleum, and of its production and refining, as are in our opinion necessary for an intelligent appreciation of those branches of the subject with which we have sought to deal. The task we have set ourselves is indicated in general terms by the subtitle, and from this it will be seen that it has been our desire to furnish a handbook which shall be of practical utility not only to officers of local authorities charged with the duties prescribed by the Petroleum Acts, but also to those engaged in the petroleum trade,

as carriers, storers, or distributors, and those who employ petroleum in industrial operations or as a source of power. It is well known that only a small proportion of the petroleum (employing the term in its generic legal sense) used in this country is under direct control through the operation of the Petroleum Acts, but it is not a matter of equally common knowledge that arrangements more or less adequate are usually adopted to provide for the safe storage of such petroleum as is not under direct legal control. We have endeavoured to indicate the principles upon which, in our opinion, the transport, storage and distribution of petroleum of various descriptions should be carried on with a view to the elimination of the special risks which experience has disclosed, and we have illustrated the nature of these risks by reference to accidents and fires which have occurred. We are hopeful that we may thus be instrumental in bringing about the general voluntary adoption in this country of such safeguards as have been shown to be essential to public safety, further legislative control being thus, so to speak, anticipated and even rendered unnecessary.

We have taken advantage of the opportunity afforded by the publication of this handbook to offer suggestions based upon the evidence taken by the Select Committee on Petroleum as to the construction and use of mineral oil lamps. Our experience, coupled with the careful study of the evidence, has led us to the conclusion that, if these suggestions were carried into effect, accidents with such lamps would be of rare occurrence.

In respect to carbide of calcium we have explained the character and properties of the material and of the acetylene gas made therefrom, and have pointed out the nature of the precautions to be taken not only in

the storage of the carbide, but also in the generation and use of the gas.

As the Petroleum Acts provide for an appeal to the Secretary of State from an adverse decision by a local authority on an application for a licence, and as the Explosives Department of the Home Office has been largely consulted on questions connected with petroleum legislation, the late Chief Inspector, Col. Sir Vivian Majendie, K.C.B., having, as is well known, devoted special attention to the subject, it is incumbent upon us to state that this handbook is in no sense official.

CONTENTS.

CHAPTER I.

INTRODUCTORY.

"PETROLEUM": what it is, as defined by law and by commercial usage respectively—Early historic references—The origin of petroleum.

PAGE

Legal definition—Legal definition a wide one 1

"Rangoon oil" and "Burmah oil"—Definition presumably limited to primary products—Mixtures included . . 2

Flash-point or flashing-point—Commercial definition—"Petroleum" generic rather than specific in commerce—Origin of the term "petroleum"—Other names for petroleum . 3

Persian "naphtha"—Asphaltum and bitumen—Maltha—Biblical references 4

Classical references—Sicilian oil—Seneca oil—Marco Polo on Baku 5

Earth-oil creek in Burma—Barbados tar—Galician oil—St. Quirinus's oil—Bitumen at Pitchford, Shropshire . . 6

Derbyshire—The origin of petroleum—Early theories . . 7

Modern theories 8

Inorganic origin: Berthelot's experiments—Researches of Moissan 9

Byasson's theory—Mendeleeff's view 10

Sokoloff's opinion—Organic origin—American opinions . . 11

Animal and vegetable origin—Höfer and Engler as to origin being animal only 12

Engler's experimental researches 13

PAGE
Explanation of results—Failure to obtain petroleum from fish —Zaloziecki's views 14
Ochsenius's views—Lesquereux's views—Critical consideration of the various theories 15
Comparative probability of organic theory—Mode of accumulation of organic remains 16
Extent of deposits—Practical illustration of formation of deposit —Processes presumably still in operation . . . 17
Objections to theory of animal origin—Trinidad deposits probably vegetable 18
Evident need of qualification of Höfer's view—Value of Engler's results 19
Conclusions as to origin—Part played by clay in aggregation —Whether formed where now found—Dr. Orton's remarks 20–21

CHAPTER II.

SOURCES OF SUPPLY.

Geographical and geological occurrence—No connection with limits of land and sea—Association with mountain ranges 22
Geological and geographical distribution of bitumens . . 23
Principal deposits in old and young rocks 24
Requisite conformation of strata—Anticlines or anticlinals—"Terrace" structure 25
Porous "reservoir" rock and impervious "cover-rock" needed —Principal porous rocks—Dolomitic limestone . . 26
Usual impervious cover—Capacity of porous rock . . . 27
Petroliferous dolomite of Chicago—Production of Pennsylvania-New York oil-field—Capacity of Baku oil-sand—Pressure in oil- and gas-wells—Russian oil fountains . . . 28
Cause of the pressure—Lesley's criticisms—Hydrostatic theory 29
Russian liquid fuel industry—Older American industry practically unaffected—Tendency to creation of numerous centres of production 30
Various producing countries—Features of the industry—"Pennsylvania" oil district 31
Lima-Indiana field—Production in the various States . . 32
Total production in United States—Aggregate output during past fortv years—The Russian petroleum industry—The various oil-fields of Baku—Production 33

PAGE
Grozni district—Production—Canadian petroleum industry—Production . . . 34
Other sources—Galicia—Roumania . . . 35
Production in Galicia—Production in Roumania—Germany . 36
Italy—United Kingdom: Shale oil—Java—Sumatra—Borneo—Japan—Burma—Assam . . . 37
Peru—Magnitude of industry as a whole . . . 38

CHAPTER III.

PRODUCTION, REFINING, ETC.

Production.

The United States—The petroleum well—Construction of the derrick—Walking-beam, &c. . . . 39
Steam-engine and boiler—Bull-wheel—Sand-reel—Control by driller . . . 40
Drilling cable—Drilling tools—Jars—Auger or drill—Sinker-bar—Reamers, &c. . . . 41
Bailer—Temper-screw—Clamps—Sand-pump—Fishing-tools . 42
Drilling a well—Conductor—Drive-pipe—Spudding—Use of drilling tools . . . 43
Rate of movement—"Dressing" the bit—Sand-pumping—Work continuous—Fishing—Casing the well . . . 44
Exclusion of water—Sizes and lengths of casing—"Torpedoing" the well—Pumping from well—Receiving tank . . . 45
Transportation and storage company—Pipe-line certificates—Early method of transport—Beginning of railway transport—Early tank-waggons . . . 46
Modern tank-car—Tank barges—First pipe-line—First trunk-line—Concentration of refining on Atlantic and Lake Erie—Pipe for trunk-lines . . . 47
Tanks—Pumping engines—"Go-devil" for clearing pipe-lines . 48
Russia—Iron rods in lieu of cable—Rod system less expeditious—Wells of greater diameter—Casing—Oil raised by bailer 49

Refining.

Size of stills—Process of fractional distillation (intermittent) . 49
Condenser--Continuous distillation—Division of distillation—Tail-house . . . 50
Chemical treatment—Paraffin separation—Process merely outlined—Scottish shale-oil industry . . . 51

MARINE TRANSPORT.

PAGE

Tank-steamers 51

Principles of construction—Isolating cofferdams—Division of oil-tanks 52

STORAGE AND DISTRIBUTION.

Ports of discharge in the United Kingdom—London wharves . 52

Smaller storage installations—Storage arrangements—Installations at Liverpool and Manchester 53

Petroleum spirit landed at Thames Haven for London—Gas-oil —Bulk distribution of kerosene 54

CHAPTER IV.

COMMERCIAL PRODUCTS OF PETROLEUM, SHALE-OIL, AND COAL-TAR.

Nature of crude petroleum—Colour—Odour—Specific gravity—Inflammability—Chemical composition 55

Division into commercial products—"Naphtha"—"Gasoline"—"Cymogene"—"Rhigolene"—Light gasoline—"·680 spirit," "petrol," motor-car spirit 56

"Benzoline"—"Petroleum ether"—Pentane 57

"Benzine"—"Refined oil": "Ordinary" and "water-white" or high-test, American—Mineral colza—Gas-oil, lubricating oils, vaseline, and paraffin from residuum—Russian petroleum products—"Benzine"—Kerosene—"Astatki" . . . 58

"Ordinary" and "high-test" kerosene—Light solar oil—Solar oil distillate (gas-oil) and lubricating oils—Astatki the principal product—Gas-oil and fuel-oil from Eastern Archipelago—Roumanian petroleum products: Kerosene and gas-oil 59

Scottish shale-oil products: Crude shale-oil—"Gasoline" and "naphtha," burning oils, gas-oil, lubricating oils, and paraffin—Brown-coal and peat products—Coal-tar and coal-tar products 60

Distillation—Benzol—Solvent naphtha—Burning naphtha—Carbolic acid—Naphthalene—Creosote oil 61

Anthracene—Pitch—Proportion of products—Production of coal-tar—Tar from coke-ovens, &c.—India-rubber solution and paints containing petroleum—Paint-dryers, &c.—Classification of petroleum, shale-oil, and coal-tar products 62

PAGE
Petroleum spirit 63
Petroleum oil 64
Lubricating oil—Solid products 65
Shale-oil products—Coal-tar products 66
Various uses of petroleum products increasing 67

CHAPTER V.

"FLASH-POINT" AND "FIRE-TEST."

Explanation of flash-point 68
Proportion of vapour necessary to form explosive mixture with the air 69
Conditions affecting flash-point 70–71
Conditions affecting inflammability of vapour mixtures . . 72
Conclusions 73
Principles on which standard should be fixed 74
"Fire-test" 75
Effect of local heating 76

CHAPTER VI.

TESTING.—FLASH-POINT, FIRE-TEST, ETC.

Kerosene: Primitive method of testing—"Open-test" and "close-test"—Tagliabue's open-test instrument . . 77
Squire's open-test apparatus: Directions for use . . . 78
Arnaboldi's open-test apparatus — Saybolt's electric tester: Directions for use 79
1868 English open-test apparatus 80
Apparatus of "the three chemists": Directions for use . . 81
Relation of results to fire-test—Insufficiency of directions for use—Defective nature of test—Keates's close-test—Abel's investigation 82
Terms of reference—Results of inquiry 83
Determination of equivalent flash-point—Mean difference 27° F. —Application of tests to 1000 samples: Results . . 84
Introduction of Abel test—Legalisation of Abel test . . 85
Length of pendulum—Use of pendulum—Use of clock or "metronome"—The action of the Abel test 86
Importance of beginning the test at a sufficiently low temperature—Use of a stirrer in the oil-cup 87

	PAGE
Suggestions as to the use of the Abel test—Necessary precautions	88
Testing india-rubber solution	89
Testing paints—Results affected by atmospheric pressure	90
Experiments at different altitudes: Results obtained—Effect of a tropical climate	91
Experiments in India and England: Results—Modification adopted	92
Directions for use of Abel test in tropical climates—Testing Burma crude petroleum—Investigation of petroleum-testing in Germany—Abel-Pensky test adopted	93
Description of the instrument	94–95
Directions for use	96–99
Table for correction of apparent flash-points to the normal barometric pressure of 760 millimetres	100
Standardising the instruments	101–103
Tagliabue's "pyrometer"	104
Directions for use	105–106
Wisconsin tester—Elliott tester: Description	107
Directions for use	108
Objection to the test	109
Granier tester: Directions for use	110
Unsatisfactory character of the test—Parrish's naphthometer	111
Foster's tester	112
Directions for use	113
Relation of results to those of Abel tester—Salleron-Urbain tester	114
Defective nature of test	115
Test-tube method of testing	116
Testing atmosphere of tanks, &c.—Use of alcohol flame—Experimental investigation—"Flame-cap"—Advantage of hydrogen flame	117
Clowes's miners' test-lamp—Redwood's test-lamp: Description	118–120
Mode of use	121
Delicacy of test	122
Density of petroleum vapour—Collection of sample—Satisfactory results given	123
Lubricating oils—Close and open flash-points and fire-test—Pensky-Martens tester—Description of the instrument	124–125
Rate of heating	126

PAGE
Freedom of sample from water essential—Gray's tester . 127
Substitute for gas—Directions for use 128
Other products—Testing mineral spirit—Testing gas-oils, &c. 129

Specific Gravity.

Hydrometer—Correction for temperature 129
Westphal balance 130

Boiling Point.

Determination of boiling point—Pressure test for petroleum spirit 130

Other Tests.

Fractional distillation test—Colour—Burning quality—Trinity House specification—Viscosity test of lubricating oils 131–132
Redwood's standard viscometer—Friction test—"Cold-test"—Loss on heating—Composition—Freedom from impurities Paraffin testing—Gas-oil testing 133

CHAPTER VII.

LEGISLATION RELATING TO PETROLEUM (HISTORICAL).

Act of 1862 134
Select committee of 1867 135
Report of the "three chemists"—Sir F. Abel's alteration . 136
Act of 1868 137
Bill of 1869 138
Act of 1871—Bill of 1872—Select Committee of 1872 . . 139
Test revised by Sir F. Abel—Act of 1879—Hawking . . 140
Act of 1881—Bill of 1883 141
Select Committee of 1883 142
Bill of 1891 143
Flash-point agitation 144
Select Committees of 1894 to 1898 145
Mr. Reckitt's Bill 146–147

CHAPTER VIII.

EXISTING LEGISLATION RELATING TO PETROLEUM.

Petroleum Acts, 1871 to 1881—Petroleum spirit not prohibited for use in lamps 148

PAGE
Scope of Acts of 1871 and 1879 149
Harbour by-laws—Forms of licence 150
Verification of testing instrument—Carbide of calcium—Scope of Act of 1881 151
Defects in existing legislation 152–154
Possibility of future legislation 155
Exemption of petroleum spirit for light locomotives . . 156

CHAPTER IX.

PRECAUTIONS NECESSARY FOR PETROLEUM.

Comparative danger of oil and spirit—Danger from naked light 157–158
Lighting of spirit stores—Electric spark 159
Lightning—Leakage 160
Tanks and vessels to be covered—Danger from empty barrels—Inflammable material—Pouring petroleum on fires . . 161
Quick-drying paints—Ventilation—Sand for extinguishing fire—Metal tanks 162
Precautions against outflow 163
Quantity in any one store 164
Petroleum not to be kept or conveyed with explosives—Precautions in conveyance—Cleansing the holds of petroleum ships 165–166
Conveyance by road and rail—Over-filling of vessels . . 167
Petroleum barrels to be covered in conveyance . . . 168
Hawking of petroleum—Danger of suffocation . 169–170

CHAPTER X.

PETROLEUM OIL LAMPS.

General construction—Choice of a lamp 171
Points of efficient construction—Stability 172
Oil container 173
Filling-hole 174
Burner 175
Chimney gallery—Wick-tube—Safety lamps 176
Management of lamps—Accidents 177
Lamp explosions 178

PAGE

Falls of lamps—Suggested legislation—Effect of raising the flash-point 179–180
Immunity from accidents in Scotland 181
Effect on price of oil 182–184
Prohibition of dangerous lamps—Importance of instruction 185–186

CHAPTER XI.

CARBIDE OF CALCIUM AND ACETYLENE.

Manufacture of carbide—Formation of acetylene . . . 187
Affinity of carbide for water—Properties of carbide—Identification—Properties of acetylene 188–189
Illuminating power—Generators 190
Legislation 191
Licences 192
Precautions 193
Quantity—Safety of generator 194
Residue—Purity of carbide 195
Harbour by-laws—Compressed acetylene 196
Exemptions—Acetylene mixed with air 197
Accidents—Other uses of carbide and acetylene . . 198–199

APPENDIX I.

Imports of petroleum into the United Kingdom . . 200–203

APPENDIX II.

Petroleum Acts, 1871 & 1879, as amended, with remarks 204–227

APPENDIX III.

Directions for drawing the sample and preparing it for testing in tropical climates—Directions for preparing and using the test apparatus in tropical climates 228–231

APPENDIX IV.

Petroleum (Hawkers) Act, 1881 232–234

APPENDIX V.

PAGE

Model Code of Harbour By-laws for Petroleum . . 235–237

APPENDIX VI.

Memorandum issued by London County Council, and forms of licence for petroleum and carbide of calcium . . 238–260

APPENDIX VII.

Regulations as to construction and verification of apparatus for testing petroleum 261–263

APPENDIX VIII.

Table for correction of observed flashing-points for variations in atmospheric pressure 264

APPENDIX IX.

Locomotives on Highways Act, 1896—Regulations dated April 26, 1900, made by the Secretary of State under Section 5, as to the keeping and use of petroleum for the purposes of light locomotives 265–267

APPENDIX X.

Specifications of tank depots and screen walls (proposed to be included in an Act of Parliament) 268–271

APPENDIX XI.

Suggestions for the care and use of petroleum lamps . 272–273

APPENDIX XII.

Carbide of calcium—Orders in Council 274–276

APPENDIX XIII.

Suggested model code of harbour by-laws for carbide of calcium 277

APPENDIX XIV.

PAGE
Explosives Act, 1875—Orders in Council relating to acetylene gas 278–283

APPENDIX XV.

London County Council—Report as to licensed premises in the County of London upon which petroleum, under the Acts, is used in trade or manufacture 284–288

APPENDIX XVI.

Scale of maximum amounts of petroleum allowed to be kept according to distance from protected works 289

INDEX 291

CHAPTER I.

INTRODUCTORY.

"Petroleum": what it is, as defined by law and by commercial usage respectively—Early historic references—The origin of petroleum.

Legal Definition.—By the Petroleum Act, 1871 (34 and 35 Vict., ch. 105), which is still in force, except as to the standard or limit of flash-point and the mode of testing, petroleum is defined in the following words:

"For the purposes of this Act the term 'petroleum' includes any rock oil, Rangoon oil, Burmah oil, oil made from petroleum, coal, schist, shale, peat or other bituminous substance, and any products of petroleum, or any of the above-mentioned oils; and the term 'petroleum to which this Act applies' means such of the petroleum so defined as, when tested in manner set forth in Schedule One to this Act, gives off an inflammable vapour at a temperature of less than one hundred degrees of Fahrenheit's thermometer."

Legal definition a wide one.

It will thus be seen that the legal definition of petroleum is a wide one, embracing liquid products, such as coal-tar, and the solid product, paraffin, which are not "petroleum" in the commercial acceptation of that term; and it will further be observed that for legal purposes, in respect to storage, an arbitrary limit, based upon the temperature at which inflammable vapour is given off, is fixed.

Rangoon oil and Burmah oil.

The reference in the definition clause to Rangoon oil and Burmah oil, which first appeared in the Act of 1868, doubtless had its origin in the circumstance that shortly before this Act was passed the produce of the Burma oil-fields was, in small quantities, first brought to this country, petroleum having previously been imported only from the United States. The name of Rangoon oil was taken from the port of shipment, "Rangoon oil" and "Burmah oil" being two names for the same substance. Petroleum now comes to this country from many other parts of the world, and there is less reason for retaining the specific mention of Rangoon oil or Burmah oil, which can scarcely be regarded as an article of commerce in the United Kingdom, than for specifying Russian oil, which is largely imported, or the oils of Roumania and Borneo.

Definition presumably limited to primary products.

Presumably only what may be described as primary products of "petroleum" are intended to be included in the definition, otherwise nitrobenzol and aniline made therefrom, and even aniline dyes, would legally be petroleum. It has, however, been successfully contended in the Courts of Law by local authorities empowered to take action under the Petroleum Acts, that mixtures containing petroleum (as defined by law), such as india-rubber solution, paints, and varnishes, come within the legal definition; therefore, if any such mixture gives off inflammable vapour below the legal limit, it can only be kept in pursuance of the provisions of the law. This may be described as a common-sense interpretation, for experience has shown that the mixtures in question may be as liable to ignition or to create, by volatilisation, an inflammable or explosive atmosphere, as certain descriptions of petroleum unmixed with other substances.

Mixtures included.

In a succeeding chapter details will be given of the

principal methods employed in ascertaining, for legal purposes, the temperature at which a sample of petroleum gives off inflammable vapour. This temperature, ascertained in accordance with the prescribed conditions, is commonly known as the flash-point or flashing-point of the oil.

Flash-point or flashing-point.

Commercial Definition.—In commerce the term "petroleum" was formerly employed to designate the oil burned in lamps, and as the flash-point of this oil is not below the limit fixed by law it followed that commercial "petroleum" was not "petroleum" to which the Acts apply. This, as will readily be appreciated, caused some confusion, and in order to avoid the inconvenience resulting therefrom the practice was adopted of applying the term "petroleum oil" to the product in question, although this obviously involves tautology. According to present commercial usage, the term "petroleum" is employed in what may be termed a generic rather than a specific sense, an additional word giving the necessary definition. Thus we have: crude petroleum which is the oil as it comes from the wells; petroleum oil, the product burned in lamps; and petroleum spirit, the more volatile products, collectively. The lamp oil is also known as petroleum distillate and refined petroleum, respectively, before and after being subjected to chemical treatment for its purification.

"Petroleum" generic rather than specific in commerce.

Origin of the Term "Petroleum."—Petroleum is found in many parts of the world oozing or flowing from outcrops of porous rock, and from this mode of occurrence it derived its name, which means, literally, rock-oil—Latin, *petra* (rock), *oleum* (oil). Equivalents of this name are found in most other languages; in German the corresponding terms *erdöl* (earth-oil), *steinöl* (stone-oil), and *bergöl* being thus employed.

Other Names for Petroleum.—Petroleum was, however, known to the Persians, Greeks and Romans

under the name of naphtha, a name which is still employed in Russia to designate crude petroleum, though elsewhere it is applied to certain descriptions of distilled petroleum spirit, and perhaps more properly should be confined to the volatile products obtained from coal-tar and wood-tar.

Persian "naphtha."

Probably the adoption of the term in Persia arose from the circumstance that before the creation of the present petroleum industry a volatile and remarkably pure description of crude petroleum of light colour was found in that country, and was in fact made use of many years ago in protecting the readily oxidisable metals potassium and sodium from the action of the atmosphere.

Asphaltum and bitumen.

The less fluid kinds of petroleum were termed ἄσφαλτος by the Greeks (hence *asphaltum*), and the Romans applied the general term of *bitumen* to the various descriptions of natural hydrocarbons, the word petroleum not being used in classic Latin. By ancient writers the names *pissasphaltum* (Greek, πίσσα = pitch, ἄσφαλτος = asphalt), and *pisselæum* (πίσσα = pitch, ἔλαιον = oil), were occasionally employed. To distinguish bitumen intermediate in consistency between petroleum and asphalt

Maltha.

the term maltha (Latin, *maltha* = cement for cisterns, roofs, &c.) is employed, the equivalent for this in Mexican Spanish being *brea.* Other names which may be mentioned as having been applied to petroleum are: earth balsam, mineral tar, *oleum Médea*, Seneca oil, Sicilian oil, and St. Quirinus's oil.

Biblical references.

In the Old Testament there are numerous references to petroleum, among which the following may be quoted: "The Vale of Siddim was full of slime pits" (Gen. xiv. 10); the word which is translated *slime* in our version appearing as *bitumen* in the Vulgate. In Genesis ix. 3, in the description of the Tower of Babel, we are told that "slime had they for mortar," whilst in Job xxxix. 6, we find, "and the rock poured me out

rivers of oil." In the Scriptures the word salt is used indiscriminately for common salt, nitre, and bitumen, and Lord Playfair suggested that the New Testament reference to salt losing its savour was meant to apply to Petroleum, which on exposure parts with its volatile constituents and thus yields asphalt, good only to be "trodden under foot of men."

Early Historic References.—Herodotus (450 B.C.) describes the collection of petroleum, which, he says, was called *rhadinance* by the Persians, from a well at Arderrica, and from the famous pitch spring in the island of Zante; he also refers to the use, as mortar, in building the walls of Babylon, of the bitumen brought down by the Is, a tributary of the Euphrates. Diodorus, Josephus and Vitruvius also mention this use of bitumen, and Dioscorides describes a piss-asphaltum obtained at Apollonia near Epidamnos (Albania). Both this writer and Pliny, among others, mention the use of Sicilian oil from Agrigentum for illuminating purposes. Plutarch gives an account of the discovery of petroleum, "having the gloss and fatness of natural oil," by an attendant of Alexander, while digging on the banks of the Oxus.

Classical references.

Sicilian oil.

The petroleum found in the State of New York was undoubtedly known to the Seneca Indians in very early days, and the burning of the oil which collected on the streams formed part of their religious ceremonies. Petroleum was also, long before the foundation of the present industry, collected in the United States and sold under the name of Seneca oil (from Lake Seneca, where it was first obtained) as a remedy for rheumatism, burns, coughs, sprains, &c.

Seneca oil.

Referring to the petroleum of the Baku district, Marco Polo describes in the thirteenth century "a fountain from which oil springs in great abundance, inasmuch as a hundred ship-loads might be taken from it at one

Marco Polo on Baku.

time. This oil," he adds, "is not good to use with food, but is good to burn, and is also used to anoint camels that have the mange."

Earth-oil creek in Burma.

The oil springs of Persia, and the renowned petroleum wells of Yenangyaung (earth-oil creek) in Burma, have been often described by travellers, and it was from the asphalt of Trinidad that Gesner first prepared kerosene. The crude petroleum of Barbados, imported under the name of Barbados tar, formerly occupied a place of some importance in the Materia Medica of this and other countries. It was thus referred to in 1750 by Griffith Hughes in his "Natural History of the Island of Barbados": "The most remarkable fossil of bituminous kind is green tar. It is obtained by digging holes or a trench, and it rises on the water. It issues from hills, and is gathered in the months of January, February and March, and serves to burn in lamps."

Barbados tar.

Galician oil.

Historical records show that from very early times crude petroleum has been collected in Austria-Hungary for use as cart-grease, and the Alstetterring, in Prague, is said to have been lighted by oil distilled from petroleum obtained in Galicia as far back as 1810, or between that date and 1818.

St. Quirinus's oil.

In 1436, petroleum from the Tegern See in Bavaria was sold under the name of St. Quirinus's oil as a medicinal agent, and in Italy a concession was granted in the year 1400 for the collection of petroleum from wells at Miano. The petroleum of Modena, which at one time was largely used for lighting and medicinal purposes, as well as in the preparation of varnishes and paints, was discovered by Ariosto, a physician of Ferrara, in 1640.

Bitumen at Pitchford, Shropshire.

The following interesting account of the occurrence of bitumen at Pitchford in Shropshire is taken from Camden's "Britannia":

"A little village call'd *Pitchford*, which formerly gave name to the ancient family of the Pitchfords, is now the possession of the Otelies. Our ancestors gave it the name of *Pitchford* from a spring of *pitchy* water; for in those days, they knew no distinction between *pitch* and *bitumen*. And here is a well in a poor man's yard, upon which there floats a sort of liquid *bitumen*, although it be every day scummed off; after the same manner as it doth on the lake *Asphaltites* in *Judæa*, and on a standing pool about *Samosata*, and on a spring by *Agrigentum* in Sicily; but the inhabitants make no other use of it than as pitch. Whether it be a preservative against the Falling-sickness, or be good for drawing and healing of wounds (as that in *Judæa* is), I know no one yet that has made the experiment. Here, and in the adjacent places, there lies over most of the Coal-pits or Mines, a *Stratum* or layer of blackish rock, of which, by grinding and boiling, they make pitch and tar, and from which also a kind of Oil is distill'd."

Oil spring in Derbyshire.

There are many other places in Great Britain where petroleum occurs in small quantities, and it is worthy of note that James Young, the founder of the Scottish shale oil industry, commercially utilised a spring of petroleum which had been met with in the workings of the Riddings Colliery at Alfreton, in Derbyshire, before he took out his celebrated patent for obtaining "paraffine oil or an oil containing paraffine, and paraffine from bituminous coals."

Early theories.

The Origin of Petroleum.—It is not surprising that a natural product of so distinctive and, one may add, of so self-assertive a character should have attracted the attention of men of science, and we find in some of the earlier treatises amusing statements in reference to the nature and origin of petroleum. Bacon in his *Sylva Sylvarum* tells us that the original con-

cretion of bitumen is a mixture of a fiery and watery substance, and remarks that flame attracts the naphtha of Babylon afar off. Macquer published in 1764 a treatise on chemistry in which bitumen is defined as a mineral substance yielding petroleum on distillation, and as an oil rendered consistent and solid by being combined with an alkali, but in the same work bitumen is described as belonging as much to the vegetable as to the mineral kingdom; the author further states that solid bitumen appears to be a vegetable oil combined with a mineral acid, and expresses the opinion that bitumens are the resinous and oily parts of trees or plants. Bergmann in his "Physical and Chemical Essays," which appeared during the years 1788–1791, expressed the view that petroleum was an example of a small proportion of water combined by means of an acid with the principle of inflammability. Amongst the earlier writers on the subject none contributed more specific and correct information than Hatchett, whose views will be found in the *Transactions of the Linnean Society* for 1798. It was, he said, generally admitted at that time that bituminous substances are not of mineral origin, "but have been formed from certain principles of substances belonging to the organised kingdoms of nature." He further specified the elementary principles (as he called them) of bitumen as carbon, hydrogen, sometimes azote and probably some oxygen, a remarkably correct definition, by the way, and from the correspondence between this composition and that of the vegetable and animal oils and resins he arrives at the conclusion that metamorphic action has produced petroleum from these sources.

Modern theories.

The latter half of the past century has been fertile in theories of the origin of petroleum, and many eminent men have devoted much thought to the

subject. The various modern theories may be broadly classified into two groups, one consisting of those which assign to the product an inorganic origin, and the other those which account for its production from animal or vegetable matter, or both.

Inorganic origin. Berthelot's experiments.

The first exponent of the theory of inorganic origin was the distinguished chemist Berthelot, who, proceeding upon the hypothesis of Daubrée that free alkali-metals exist in the interior of the earth, ascertained experimentally that when carbonic acid or an earthy carbonate acts upon the alkali-metals at a high temperature, acetylides are formed, and that these bodies when acted upon by water-vapour, under the conditions prevailing in the earth, yield hydrocarbons resembling those of American petroleum, the precise composition of the hydrocarbons varying with the temperature. He therefore in 1866 expressed the view that petroleum may have been produced by the infiltration of water containing carbonic acid into the interior of the earth, where it would be brought into contact with the alkali metals at an elevated temperature. Many years later Maquenne prepared acetylide or carbide of barium (C_2Ba) and obtained acetylene by its action on water, and still more recently through the discovery of Willson, one of the carbides, viz., that of calcium, has become an ordinary article of commerce, and acetylene a common illuminating agent.

Researches of Moissan.

Of still greater interest, however, in connection with the subject we are considering, have been the results of the work of Moissan, who has found that certain of the carbides yield liquid hydrocarbons on decomposition with water. In a paper published in the *Journal of the American Chemical Society* in 1899, Mr. J. A. Matthews has given the following classification of the reactions of decomposition of the carbides:

(1) The carbides of lithium, sodium, potassium,

calcium, barium and strontium are decomposed by water, giving mostly acetylene.

(2) Silver, copper, mercury and gold (?) acetylides are acted on by hydrochloric acid, giving acetylene.

(3) Aluminium and beryllium carbides react with water, yielding methane.

(4) Manganese carbide with water gives methane and hydrogen.

(5) The carbides of yttrium, lanthanum and thorium are decomposed by water, giving mixtures of acetylene, ethylene, methane and hydrogen.

(6) Lanthanum, cerium and uranium carbides give with water, besides the volatile products, a residue of liquid and solid hydrocarbons.

It will thus be seen that several of the carbides, including that of manganese, yield methane (CH_4), the lowest member of the paraffins present in Pennsylvania petroleum, and that some actually yield liquid and solid hydrocarbons.

Byasson's theory.

In 1871, Byasson, in a memoir on the origin of petroleum published in Paris, suggested that petroleum might have resulted from the action on iron or sulphide of iron at a white heat, of steam and carbonic acid gas, resulting from the infiltration of salt water to great depths in the earth, his theory, like that of Berthelot, being based upon laboratory experiments in which petroleum was obtained.

Mendeleeff's view.

In 1877 Cloez obtained petroleum-like hydrocarbons by the action of dilute mineral acid or even boiling water on a spiegeleisen (carbide of iron and manganese), and the eminent Russian chemist Mendeleeff gave the weight of his authority to the view that petroleum is of inorganic origin. The great density of the earth, and the well-known presence of iron in meteorites, in the solar system (as shown by the spectroscope), and in eruptive rocks, are regarded by Mendeleeff as

evidence that the interior of the earth contains large amounts of iron. Accepting the igneous theory of the formation of the earth, it is reasonable to conclude that the core of this spheroid may largely contain carbide of iron, and that as cooling of the molten mass progressed, and the outer crust became crumpled and cracked through the shrinkage of the central portion, forming valleys which were subsequently occupied by the seas when the cooling had progressed sufficiently to admit of the condensation of the dense cloud of aqueous vapour, water would by gravitation naturally find its way through the crevices towards the centre of the still highly-heated mass. In these circumstances it is evident that the chemical action which would be set up under the favourable conditions of high temperature and great pressure would probably produce hydrocarbons, the hydrogen of the water combining with the carbon of the carbide and the oxygen combining with the iron.

Sokoloff's opinion.

The Russian geologist Sokoloff, on the other hand, has expressed the opinion that hydrogen and carbon may not improbably have entered into direct combination at an early stage in the earth's history, that the hydrocarbons thus formed may have been absorbed by the mass of the earth whilst the latter was still in a glowing viscid state, and that these hydrocarbons may subsequently have been transferred to the outer layers where they are now found. Other authorities, amongst whom are Coquand, Grabowski and Hitchcock, regard petroleum as not improbably a condensation-product of marsh gas.

Organic origin. American opinions.

The majority of American geologists who have devoted special study to the question are agreed as to the organic origin of petroleum, and are of opinion that it is derived both from vegetable and from animal remains. Lesley has expressed the view that the oil of

Pennsylvania has been formed from fossil fucoids and corals, of which remains are found in limestone beds many thousand feet thick, beneath the Venango oil-sands, and Ashburner concurs generally in this view of a dual origin. Orton considers that the oil occurring in shale and sandstone is of vegetable, and that found in limestone of animal, origin. Peckham suggests that oil with an asphalt base is of animal origin, whilst that which contains paraffin (solid hydrocarbons) is derived from vegetable organisms. Strippelmann considers that petroleum and natural gas were probably produced from vegetable and animal remains in Silurian, Devonian, and Carboniferous formations. Orton expresses the view that the petroleum of California is derived from the animal remains with which the oil-bearing shales of the district were originally filled, and he adds that the similarity of the oils of Canada, Kentucky, Tennessee, and North-Western Ohio with the Californian oil points to a common origin. In a paper on the nitrogen content of California bitumen Peckham asserts that his discovery of basic oils in the petroleum of California "establishes beyond any question the animal origin" of such petroleum.

Animal and vegetable origin.

Höfer and Engler as to origin being animal only.

As opposed to the dual theory of origin some eminent authorities on the European continent contend that petroleum is solely or mainly of animal origin. The most noted exponents of this view are Höfer and Engler. The former did not originate the view in question, but was the first to marshal facts in support of it, whilst the latter by his cogent arguments, supported by practical experiments, has been largely instrumental in gaining adherents to the theory. Höfer's arguments in favour of an animal origin are summarised as follows:

(1) Oil is found in strata containing animal, but little or no plant remains. This is the case in the Car-

pathians and in the limestone examined in Canada and the United States by Sterry Hunt.

(2) The shales from which oil and paraffin were obtained in the Liassic oil shales of Swabia and of Steierdorf in Styria contained animal, but no vegetable remains. Other shales, as, for instance, the copper shales of Mansfeld, where the bitumen amounts to 22 per cent., are rich in animal remains, and practically free from vegetable remains.

(3) Rocks which are rich in vegetable remains are generally not bituminous.

(4) Substances resembling petroleum are produced by the decomposition of animal remains.

(5) Fraas observed exudations of petroleum from a coral reef on the shores of the Red Sea, where it could only be of animal origin.

Engler's experimental researches.

In his experimental researches already alluded to Engler distilled 490 kilos. of menhaden (fish) oil at a high temperature and under considerable pressure, and thus obtained a distillate resembling petroleum. The distillation was commenced at a temperature of 320° C. under a pressure of ten atmospheres, and was completed at 400° C. under a pressure of four atmospheres. He thus obtained about 60 per cent. of distillate, of specific gravity ·8105, about 8·9 per cent. of gas, and about 5 per cent. of unsaponifiable fat in the residue. The distillate was brown, and possessed a greenish fluorescence and a disagreeable, acrolein-like smell. By fractionation, the distillate yielded pentane, hexane, normal and secondary heptane, and normal octane and nonane. From the chemical reactions of the distillate, the presence of olefines, naphthenes and other aromatic hydrocarbons was inferred. Finally, from the distillate a lighting oil was separated, which was described as indistinguishable from commercial kerosene, and this statement one of the authors is in a position to confirm,

having received from Professor Engler a specimen of the product.

On repeating the experiments with triolein (commercial "oleine") similar results were obtained; in fact the menhaden oil used may be considered to consist of olein, stearin, and palmitin. The composition of the oil is such that after combination of all the oxygen with part of the hydrogen to form water, the residue contains carbon and hydrogen in about the same proportions as those in which they are present in petroleum.

Explanation of results.

Engler considers that the glycerin or the acrolein formed during the reaction would be washed away from the petroleum, but Neish has given a more elaborate explanation of their disappearance. He suggests that by elimination of water and by condensation, the acrolein formed from the glycerin under the action of heat and pressure becomes itself converted into benzene; he further expresses the opinion that the carbon dioxide produced concurrently with the liquid hydrocarbons from the fatty acids may have become reduced to carbon monoxide and ultimately into hydrocarbons, by the influence of dissociated hydrocarbons.

Failure to obtain petroleum from fish.

It should be added that all attempts by Engler to obtain similar products from fish and other animal remains were totally unsuccessful. Engler therefore concludes that some change in the animal remains must have taken place in the earth, whereby all nitrogenous and other matters, save fats, were removed, the petroleum being formed from the fat alone, by the combined action of pressure and heat, or by pressure only.

Zaloziecki's views.

Zaloziecki, who is an adherent to the theory of animal origin, believes that the first products of the decomposition of animal bodies would be nitrogenous

matter and *adipocere*, which comprises the fatty matter of the remains, and that the adipocere would become covered with sediment and gradually converted into fatty acids, which finally decompose into hydrocarbons. He is of opinion that adipocere, ozokerite, and liquid petroleum are produced in the order named.

Ochsenius's views. Ochsenius considers that the halogens in the water found with petroleum have had much to do with the production of the petroleum, being of opinion that the fatty matters of decomposing animal bodies are converted into petroleum under the action of certain salts, notably alkaline bromides and aluminium chloride. Zaloziecki, however, points out that the water found with petroleum is not always saline, and expresses the view that the action of salt is merely to arrest putrefaction.

Lesquereux's views. Lesquereux states that at Lund (Scania) masses of seaweed change into viscous fetid oily matter, saturating the sand with which they are intermixed, and retaining no trace of structure. The Sardinian salt-marshes are also occasionally covered with fucus, which decomposes into oil. He regards the Pennsylvanian petroleum as due to marine vegetation, whilst coal is derived from terrestrial fibrous plants. Such marine vegetation abounds throughout the Silurian and Devonian rocks.

Critical consideration of the various theories. Broadly it may be said that the theories which ascribe an inorganic origin to petroleum are considered inadmissible by most geologists and others who are acquainted with the conditions under which the many widely-different descriptions of the product are met with. It must be admitted that when such eminent chemists as Berthelot and Mendeleeff give the weight of their authority to the theories already described, the question deserves the most careful consideration. A distinction must, however, be drawn between the

abstract or theoretical possibility of petroleum having been produced by the agencies referred to, and the probability that it was actually so produced. The more recent investigations of Moissan may be said to afford experimental proof of the possibility of hydrocarbons having been generated from metallic carbides, but previous to these investigations that possibility was not doubted. The question is not whether the assumed reactions would yield petroleum, but whether in the light of facts derived from a study of the known deposits of petroleum it is reasonable to conclude that the oil found in such deposits had its origin in these reactions, and, of course, in dealing with this question we are necessarily to some extent hampered by the proverbial difficulty of proving a negative. In this connection it has been pointed out by Phillips that practically no free hydrogen is found in natural gas, and that this gas must have been produced concurrently with hydrocarbons by the action of steam upon metallic carbides. Also, that whilst paraffins alone cannot be produced by such chemical reaction, the gaseous product resulting from the action of dilute sulphuric acid upon ferromanganese contains six per cent. of olefines, and natural gas contains neither olefines nor carbon monoxide. The strongest argument, however, against the inorganic theory lies in the extreme probability and generally highly satisfactory character of the organic theory, based as the latter is upon logical deductions drawn from a careful study of the principal deposits of petroleum.

Comparative probability of organic theory.

Mode of accumulation of organic remains.

We may now proceed to consider the mode of accumulation of the vegetable and animal remains from which we may reasonably conclude that the petroleum of commerce was produced, and the nature of the chemical changes which the deposits underwent.

We shall then be in a position to form a judgment as to how far those who have practically rejected the theory of dual organic origin, and pinned their faith to the view that animal remains were practically the sole source, are justified in taking that attitude.

Extent of deposits.

Whether we regard petroleum as the product of the decomposition of vegetable matter or of animal organisms or of both, it is necessary to assume the existence of adequate deposits of these bodies. It is not, however, difficult to account for such accumulation. In the comparatively deep and quiescent water along the margin of the land there would be abundant opportunity for the deposition not only of the remains of marine animals and plants, but also of vegetable matter brought down to the coast by the water courses, and the changes which the earth has undergone would result in the burial of these substances under sedimentary mineral matter, the deposits thus formed being ultimately, as the result of further alterations in the earth's surface, in some cases found occupying positions far removed from the sea and often beneath immense thicknesses of subsequent deposits. It has been pointed out by Andrusov that the conditions present in the Karabugas gulf in the Caspian Sea afford an excellent illustration of the manner in which the accumulation probably occurred. Into this gulf fresh-water streams are discharging large quantities of vegetable matter and fish. The latter are killed by the strongly saline water, but this water prevents putrefaction of the remains, and as there are no animals to feed upon these remains, deposits of organic matter are speedily formed.

Practical illustration of formation of deposit.

Processes presumably still in operation.

It may, therefore, be said that, at any rate as regards the formation of suitable deposits, the processes by which we may assume petroleum to have been formed are in operation at the present time,

and we may probably even go so far as to say that ultimately the vegetable and animal remains now being deposited may in part give rise to further stores of oil for the use of future generations. It should, however, be remarked that obviously a special process of decomposition is needed to produce the result, and we have now to consider the nature of the changes which produced petroleum from vegetable and animal remains.

Objections to theory of animal origin.

Attention has already been drawn to Höfer's arguments in favour of the animal-origin theory, and it now becomes necessary to consider the other side. As Zuber has recently pointed out, it is true that the petroliferous fish-shales, the Menilite shales, as they are called, of the Carpathian oil-fields contain remains of marine animal life, but this formation is not the only, or indeed the principal, oil-producing horizon of that district, the most important one, the Eocene, also the Ropianka calcareous shales, containing but few distinguishable fossils and animal remains in particular, though by no means lacking in organic residues. Moreover the hieroglyphs and pseudo-fucoids of the Flysch system, which were at one time considered to be animal remains, are now by many regarded as probably vegetable. Furthermore, the highly petroliferous and ozokerite-bearing sub-Carpathian Miocene saliferous clay formation at Boryslaw in Galicia, though yielding practically no animal remains, is rich in undoubtedly vegetable residues, notably fir-cones, partly carbonised, partly converted into ozokerite, and embedded in rock salt.

Trinidad deposits probably vegetable.

Wall has pointed out that in addition to the Pitch Lake there are in Trinidad deposits of bitumen *in situ*, confined to particular strata which were originally shales containing vegetable remains. Wall considers that these have undergone what he terms a special mineralisation,

producing a bituminous matter instead of coal or lignite, this operation being in his opinion not attributable to heat, but being due to chemical reactions at the ordinary temperature and under the normal conditions of climate. Wall also mentions the occurrence of wood partially converted into bitumen, which when subjected to the action of a suitable solvent leaves woody tissue. One of the authors has in his possession specimens of soft woody fibre containing petroleum, which were found by the late Mr. George Scott in strata yielding small quantities of oil and gas at depths of 40 to 50 feet and 60 to 70 feet, during the drilling of a well at Digboi, Assam, in 1893.

Evident need of qualification of Höfer's view.

From these remarks it would appear that the deduction drawn from Höfer's argument that petroleum is found in primary deposits accompanied by animal remains, but never more than slightly by the remains of plants, requires much qualification.

Value of Engler's results.

As regards the support which the results obtained experimentally by Engler are held to lend to the theory of animal origin, it should be remembered that the material operated on was a fatty oil or a fatty acid, and that similar results were not obtained by the distillation of fish-tissue under like conditions. Assuming petroleum to have been formed in nature by the decomposition of a neutral fat, such as olein, it is possible that the source of such oil may at any rate in part have been vegetable and not animal remains. It should be added that most authorities are agreed that the chemical changes which have resulted in the conversion of vegetable or animal matter, or both, into petroleum, have occurred, possibly or probably under great pressure, but at ordinary or very moderate temperatures, whilst Engler's results were obtained at high temperatures. It is true that it may be

contended that very prolonged action at ordinary temperatures may produce the same effect as a short exposure to a much higher temperature, but this is not invariably the case.

Conclusions as to origin. Whatever may have been the precise nature of the chemical changes which have occurred, it does not seem reasonable to regard animal remains as the sole source, and the view which appears to be generally held by authorities in the United States is that petroleum of which the oil of Pennsylvania may be taken as the type is probably of vegetable origin, whilst certain other descriptions, such as that of Canada, are equally probably of animal origin.

Part played by clay in aggregation. In the aggregation of the petroleum it is possible that clay has played an important part, for it has been noticed that this substance possesses in a high degree the power of absorbing mineral oil.

Whether formed where now found. Within the limited space available in this work it is impossible to discuss in detail the question whether petroleum was formed where it is now found, and the following remarks of Dr. Orton, which summarise in a judicial spirit the conclusions of geologists in reference to the oil-fields of the United States are therefore quoted:

Dr. Orton's remarks. "Petroleum is undoubtedly indigenous to, and derived from, certain limestones, as Hunt has so strongly asserted. The Trenton limestone is undoubtedly the most important source of oil and gas in the geological scale of the United States at the present time. On the other hand, Newberry's doctrine, that the great supplies of the Pennsylvania field are derived from Devonian shales, is becoming more firmly established and more generally accepted every year, though it seems likely that he has laid too much stress on bituminous shales. In other words, the theories are

not exclusive of each other. Different fields have different sources. We can accept, without inconsistency, the adventitious origin of the oil in Pennsylvanian sandstones, and its indigenous origin in the shales of California, or in the limestones of Canada, Kentucky or Ohio."

CHAPTER II.

SOURCES OF SUPPLY.

Geographical and Geological Occurrence.—It is often erroneously supposed that petroleum is a comparatively rare substance, the truth being that there is scarcely any part of the globe in which traces of it do not occur. It is an equally common mistake to imagine that the discovery of petroleum is necessarily of commercial importance. Whilst there are few substances more widely distributed in nature, the conditions requisite for the formation of a valuable store of the material unfortunately exist only in a limited number of localities, although, as is well known, the areas in which it occurs in abundance are extensive.

No connection with limits of land and sea.

No fixed connection has been shown to exist between the localities where petroleum is known to occur and the present limits of land and sea; equally rich, and equally scanty, deposits being found inland on the continents, and in the oceanic islands. Bitumen is also met with to about an equal extent in the tropics, the temperate regions, and the polar districts, but the greater part of the oil-fields of the world are situated north of the equator.

Association with mountain ranges.

Attention has been drawn by several writers to the circumstance that the principal petroleum deposits are intimately associated with the great mountain ranges. Thus Peckham states in his admirable Census Report on Petroleum that in the New World oil is found at

the North-West in Alaska and in the Mackenzie district, whilst other producing areas extend from Point Gaspé in Quebec to Nashville in Tennessee; from San Francisco to San Diego; from Northern Nebraska along the Missouri river, and directly south of the Gulf of Mexico; from Cuba through the Leeward and Windward Islands to Trinidad and thence along the northern portions of South America to the Magdalena River, and southward to Cape Blanco in Peru.

In the Old World, passing westward from Baku, we find oil at many points along the range of the Caucasus Mountains, whilst on the northern and southern slopes of the Carpathians we have the well-known deposits of Galicia and Roumania.

No necessary relation as regards origin.

It must not, however, be assumed that there is any connection between the origin of petroleum and the positions of the deposits in relation to the mountain ranges, the rational explanation of the "intimate association" referred to being that it is usually in the neighbourhood of the mountains that the strata have by the same changes as those which created the mountains and valleys been thrown into a form suitable for the aggregation of the oil.

Geological and geographical distribution of bitumens.

Some form of bitumen appears to have been produced in all the principal divisions of geological time, and in the following table, prepared by Mr. W. H. Dalton, the various localities in which bitumens have been found in large or small quantities are classified geologically:

QUATERNARY .	Lancashire, Schleswig-Holstein, Red Sea, Mexico.
PLIOCENE . .	Italy, Sumatra, Borneo, New Zealand.
MIOCENE . .	Auvergne, Italy, Algeria, Egypt, Zante, Roumania, Austria, Caucasus, Persia, Turkestan, Assam, Burma, Eastern Archipelago (Java, Sumatra, Borneo, &c.), Japan, Alaska, California, Mexico, West Indies, New Zealand.

OLIGOCENE . .	Switzerland, Elsass, Galicia, Caucasus, Alaska, and other areas included under Eocene or Miocene by various authors.
EOCENE . .	Spain, Italy, Egypt, Turkey, Roumania, Austria, Caucasus, Baluchistan, Punjab, Assam, Burma, Eastern Archipelago, Utah, Texas, Mexico, New Zealand.
CRETACEOUS . .	Switzerland, Hanover, Greece, California, Wyoming, Colorado, Athabasca, New Zealand.
NEOCOMIAN . .	Spain, East France, Switzerland, Hanover, Austria, Roumania, Syria, Venezuela, West Indies and other areas includod under Cretaceous by various authors.
JURASSIC . .	England, Switzerland, Elsass, Hanover, Colorado, Mexico, Argentina and possibly other South American regions.
TRIASSIC . .	Elsass, Hanover, Punjab, China.
PERMIAN . .	Autun, Saxony.
CARBONIFEROUS .	Great Britain, South Russia, Central and Eastern United States, New Brunswick. Some of the deposits now assigned to the Carboniferous were formerly classified with the Devonian.
DEVONIAN . .	England, North Russia, Ontario.
SILURIAN . .	East Canada, Central and Eastern United States, Newfoundland.
CAMBRIAN . .	British Columbia and Alberta (Kootenay Pass).
ARCHÆAN . .	Sweden (bituminous gneiss of Nullaberg), East Canada (graphite).

Principal deposits in old and young rocks.

Whilst, however, petroleum occurs in all the chief geological divisions, the important deposits are all found either in the older rocks or in the comparatively young Tertiary formation, the intermediate periods yielding far less abundantly. In this connection it may be mentioned that the beds which do not yield oil are in general just as well fitted to hold and discharge it as those which produce it abundantly, but the conditions requisite for the formation or preservation have been absent.

Requisite conformation of strata.

Anticlines or anticlinals.

"Terrace" structure.

A certain conformation of the strata is requisite for the concentration of the petroleum product in such strata, and it has long been recognised that the anticlinal* or terrace-structure which characterises the principal oil-fields is a most important factor in the accumulation of the oil. The anticlines, which have been formed by the slow contractile movements of the earth already referred to, usually occur as a series of broad low arches, separated by synclines. They often extend for long distances, and with great regularity, but are not infrequently crossed by subsidiary anticlines, which themselves play a not unimportant part in the aggregation of the oil. Owing to difference of density the oil and water present separate into two layers, the upper consisting of oil which fills the anticlines, whilst the water remains in the synclines. Any gas which may be present rises to the summits of the anticlines. When the slow folding of the strata is accompanied by a gradual local descent, a modified or "arrested" anticlinal structure known as a "terrace" is produced, the upheaving action at that part being sufficient only to arrest the descent which would otherwise occur. The terraces may thus be regarded as flat and extended anticlines. They need not be horizontal, and sometimes have a dip of a few feet per mile, as in the case of the Ohio and Indiana oil-fields, where the dip varies from 1 to 10 feet. These slight differences in level, however, are found to have a most powerful effect in the direction already mentioned. Generally, it may be said that the strata from which the main supplies of oil and gas have been obtained in the United States are usually unbroken, nearly horizontal, and but little disturbed.

* When strata lie in this shape ⌒, they are said to form an anticlinal or anticline; when in this shape ‿, a synclinal or syncline.

The importance of the anticlinal structure has been equally observed in the oil-fields of the Caucasus, the Carpathians and elsewhere.

Porous "reservoir" rock, and impervious "cover-rock" needed.

The formation of large deposits of petroleum is, however, dependent upon something more than we have yet considered. We may have the necessary deposit of organic matter, subjected to the requisite conditions to effect its conversion into petroleum, and we may have the anticlinal structure favouring the accumulation of the oil produced, but in addition we need a rock of sufficient porosity to serve as a reservoir for the oil, and above it an impervious stratum to preserve the oil from evaporation and oxidation, and from being displaced by water.

Principal porous rocks.

The principal deposits which provide the necessary porosity for the storage of the oil are sandstones, conglomerates, and limestones. Shaly sandstones and slaty shales also serve as reservoir-rocks in a lesser degree. In the case of limestones, a natural porosity, such as is found in the coarsely-crystalline varieties, or a certain amount of chemical change resulting in the formation of interspaces capable of receiving the oil, appears to be necessary for the formation of a true reservoir-rock. Such change is usually dolomitic, consisting in the conversion of the calcium carbonate forming the limestones into the double carbonate of calcium and magnesium known as dolomite, this occupying less space than the unaltered limestones. It is therefore characterised by the production of such numerous spaces between the dolomite crystals that the rock becomes capable of retaining a large volume of oil. This dolomitic change appears to be capable of occurring only in the purer limestones. The Trenton limestone, for instance, is thus modified only where almost free from silica, the changed parts showing about 54 per cent. of calcium carbonate and 44

Dolomitic limestone.

per cent. of magnesium carbonate. A large proportion of the Trenton limestone is too impure to permit of the change, and is destitute of oil and gas. Even in rich oil-fields the dolomite has only been formed in a small portion of the stratum. When followed northward in Ohio and Indiana, the Trenton limestone is found to have become dolomitic through a small thickness only of its upper beds. The changed and unaltered portions occur at short intervals, but only the former contain the oil and gas. The change usually affects from 10 to 50 and in some cases 100 feet of the stratum, and has occurred along a line passing into Indiana through the principal oil and gas fields of Ohio.

Usual impervious cover. In addition to possessing a porous structure, the reservoir-rock must be entirely covered by an impervious layer, the commonest and most perfect cover being a fine-grained shale, whose imperviousness and freedom from fracture are essential to the complete preservation by the reservoir-rock of its liquid or gaseous contents. The fractured character of the strata in Central and Eastern Pennsylvania may account for the absence of oil and gas in these districts. In oil-bearing territory the occurrence of a porous rock beneath a cover-rock usually results in the formation of an oil-field.

Capacity of porous rock. As regards the capacity of the various oil strata to serve as an oil reservoir, experiments performed on the rock itself have shown that an oil-bearing pebble-rock may contain one-tenth or even one-eighth of its bulk of oil; and, as Carll has observed, the pores of the rock would permit of the ready removal of the largest supplies ever obtained, without the necessity for the channels which were at one time supposed to exist. The dolomitised portions of the Trenton limestone have been found to possess about the same capacity. Orton has pointed out that if a stratum a few hundred feet

in thickness carries but one-tenth per cent. of petroleum, every square mile of such territory would contain more oil than has ever been removed from a like area of the most productive field; and, taking Sterry Hunt's calculation of the oil contents of the petroliferous dolomite of Chicago as a basis, he has determined the probable contents of the almost universally-petroliferous Waterlime stratum of Ohio. Estimating, he says, its petroleum content at one-tenth of one per cent. and the thickness of the stratum at 500 feet—both of which figures are probably within the limits—we find the petroleum contained in it to be more than 2,500,000 barrels to the square mile. The total production of the great oil-field of Pennsylvania and New York to January 1885 was 26,000,000 barrels. It would require only three ordinary townships, or a little more than 100 square miles, to duplicate this enormous output from the Waterlime alone. These estimates would account for a yield far exceeding the amount that has actually been obtained, although, as pointed out by Ashburner, small areas of the best fields of Pennsylvania have yielded as much as 900,000 barrels per square mile. In the enormously rich petroliferous region of Baku the oil-sand is estimated to contain one-fifth of its bulk of petroleum.

Petroliferous dolomite of Chicago.

Production of Pennsylvania-New York oil-field.

Capacity of Baku oil-sand.

Pressure in oil- and gas-wells.

Oil and gas are met with in drilled wells not infrequently under great pressure, the highest pressures occurring as a rule in the deepest wells. The closed pressure in the Trenton limestone in Ohio and Indiana is about 200–300 lbs. per square inch, although a much higher pressure has been registered in many wells. The gas-wells of Pennsylvania indicate about double the pressure of those drilled in the Trenton limestone, 600–800 lbs. not being unusual, and even 1000 lbs. having been recorded. The extremely high pressure under which the oil is met with in wells drilled in

Russian oil fountains.

some parts of the Russian oil-fields is a matter of common knowledge, and a fountain or spouting well resulting therefrom is one of the "sights" of the country. A famous fountain in the Grozni oil-field in the northern Caucasus, which began to flow in August 1895, was estimated to have thrown up during the first three days 1,200,000 poods (over 4,500,000 gallons, or about 18,500 tons) of oil a day, quickly destroying the derrick which had been erected. It flowed continuously, but in gradually diminishing quantity, for fifteen months, and afterwards periodically.

Cause of the pressure.

The following theories have been propounded to account for the pressure:

(1) That it results from the weight of the overlying strata.

(2) That it is due to water-pressure, as in artesian wells, the percolating water which enters the stratum at its outcrop forming the "head."

(3) That it is caused by the gradually accumulating gas having had no opportunity for escaping, and being thus brought into a highly compressed condition.

Lesley's criticisms.

Lesley has pointed out that the first theory is evidently untenable, and is now practically abandoned. Even the most friable of the reservoir-rocks is capable of resisting the pressure of the overlying deposits; thus the weakest portions of the Trenton limestone have been shown to withstand a crushing weight of 720 tons to the square foot, whereas the pressure on the stratum at the bottom of a well of over 1000 feet in depth would be only about 80 tons. The rocks are also found perfectly compact at all depths reached by the drill.

Hydrostatic theory.

The hydrostatic or artesian theory has many distinguished advocates, and has been particularly upheld by those who have studied the great gas-fields of Ohio and Indiana; whilst, on the other hand, it appears to

be quite inapplicable to the fields of Pennsylvania and New York, where, if not in all other fields, the third theory is evidently perfectly tenable.

Sources of Commercial Supplies.—At one time the world's supplies of petroleum products were almost wholly contributed by the United States, but for some years past very large quantities have been obtained from Southern Russia, and the output of crude petroleum in Russia is now greater than that of the oil-fields of America. The Russian petroleum industry has, however, long since become a fuel industry, the original primary product for use in lamps now occupying the position of a by-product in the manufacture of the fuel-oil (*astatki*), of which the crude oil yields about 60 per cent., and only a comparatively small proportion of the less volatile hydrocarbons being converted into lubricating oils and gas-oil. It will thus readily be understood that it has been possible to build up a business of immense magnitude and importance without much interference with the older petroleum industry of the United States; and it may be added that the effect of such competition as has arisen has been more than balanced by increased consumption, so that the American petroleum industry may be said to be in a more flourishing condition than at any previous period in its history.

Russian liquid fuel industry.

Older American industry practically unaffected.

The present tendency is, unquestionably, in the direction of the development of a number of more or less local centres of production, with the result that a gradually-increasing number of countries are contributing to meet the ever-growing demands for petroleum products. At the same time it seems probable that, owing largely to the suitability of the crude oil found in a large number of the United States oil-fields for the manufacture of the whole series of the usual commercial products, the American petroleum

Tendency to creation of numerous centres of production.

trade will long continue to occupy a position of supremacy in respect of such products.

Amongst other countries in which petroleum is obtained in large quantities are Canada, Galicia, Roumania, the Eastern Archipelago (Java, Sumatra, and Borneo), Burma and Japan. It is also produced in Elsass, Italy, Assam, and Peru, and is known to occur in many other places in Russia and the United States besides those in which it is being worked, also in the North-West Territories (in the district of Athabasca), the Province of Quebec (near the extremity of the Gaspé peninsula), Ecuador, Colombia, Mexico, Alaska, Algeria, Hungary, the Gold Coast, Newfoundland, the West Indies, and New Zealand.

Various producing countries.

The United States Petroleum Industry.—According to the report of the United States Geological Survey on the production of petroleum in the United States during the year 1899 (the report for 1900 is not yet issued), compiled by Mr. F. H. Oliphant, the most conspicuous features of the industry for that period were (1) the total production was considerably in excess of that of the previous year; (2) there was a large increase in the number of wells completed in both the Appalachian and the Lima-Indiana oil-fields; (3) in South-Eastern Ohio and in Texas there was a largely increased production; and (4) only about 7 per cent. of the total production was obtained outside the Appalachian and Lima-Indiana fields.

Features of the industry.

The Appalachian field includes all the districts producing what is known as "Pennsylvania oil." It extends from Wellsville in New York State on the north-east, through western Pennsylvania into West Virginia, and includes a large portion of south-eastern Ohio. Its extension through Kentucky and Tennessee into northern Alabama has not been attended with

"Pennsylvania" oil district.

any noteworthy developments. The total production in the Appalachian field for 1899 was 33,050,076 barrels, as compared with 31,711,857 barrels in 1898. The greatest increase was in south-eastern Ohio, where the output was more than doubled, and the greatest falling off was in Pennsylvania.

Lima-Indiana field.

The Lima-Indiana field includes the whole of Indiana and that portion of north-western Ohio in which Lima petroleum, found in the Trenton limestone, is produced. The production decreased from 20,321,323 barrels in 1898 to 20,225,356 barrels in 1899.

Production in the various States.

The following is a tabular statement of the production in the various States for the years 1897, 1898, and 1899 :

State.	PRODUCTION.		
	1897. Barrels.	1898. Barrels.	1899. Barrels.
New York	1,279,155	1,205,250	1,320,909
Pennsylvania	17,982,911	14,743,214	13,053,603
West Virginia	13,090,045	13,615,101	13,910,630
Ohio	21,560,515	18,738,708	21,142,108
Indiana	4,122,356	3,730,907	3,848,182
Kentucky	322	5,568	18,280
Missouri	19	10	132
Colorado	384,934	444,383	390,278
California	1,903,411	2,257,207	2,642,095
Texas	65,975	546,070	669,013
Indian Territory	625	0	0
Illinois	500	360	360
Wyoming	3,650	5,475	5,560
Kansas	81,098	71,980	69,700
	60,475,516	55,364,233	57,070,850

The total production of crude petroleum in the United States during 1899 was 57,070,850 barrels (of 42 American gallons or about 35 Imperial gallons), as compared with 55,364,233 barrels in 1898 and 60,475,516 barrels in 1897. **Total production in United States.**

The aggregate output of the oil-fields of the United States during the past forty years (up to the end of 1899) amounts to no less than 943,513,609 barrels. If we allow 5·6 cubic feet to one barrel of petroleum, this quantity of oil would fill a space equivalent to 5,283,676,210·4 cubic feet. The sides of a cube to contain this volume of oil would have to be 1741·7 feet in length. This amount of oil would fill a tank with a base of one square mile to a height of 189 feet. It would fill 31,450 iron tanks of 30,000 barrels capacity, and these tanks, touching side to side, and placed in a straight line, would extend a distance of nearly 480 miles. Of this great total, Pennsylvania has furnished 62 per cent.; Ohio, 23 per cent.; West Virginia, 9·3 per cent.; Indiana, 3 per cent.; and California, 1·5 per cent.; leaving 1·2 per cent. as the quantity furnished by the other States producing petroleum. **Aggregate output during past 40 years.**

The Russian Petroleum Industry.—The producing territory in the Baku district comprises the oil-fields of Balakhany, Sabuntchi, Romany, Binagadi, and Bibi-Eibat, the aggregate area being under ten square miles. The Balakhany-Sabuntchi territory, and the adjoining districts of Romany and Binagadi, are situated on the Apscheron peninsula, about eight miles north-east of the town of Baku, whilst the Bibi-Eibat field lies two to three miles south of Baku. The production of these fields during the last three years (1897 to 1899) has been as follows: **The various oil-fields of Baku.** **Production.**

District.	1897 Poods.	1898 Poods.	1899 Poods.
Balakhany . .	100,336,495	108,836,439	114,854,151
Sabuntchi . .	162,610,054	179,828,697	230,757,289
Romany . . .	96,266,133	100,523,699	98,581,782
Binagadi . . .	197,462	227,730	213,386
Bibi-Eibat . .	62,514,479	96,526,783	80,840,807
	421,924,623	485,943,348	525,247,415

1 pood = 36·1127 lbs. avoirdupois. *Note.*—In comparing the production of crude petroleum in Russia with the production of crude petroleum in the United States, 8 poods may be taken as the equivalent of the American "barrel" unit.

Grozni district. In the year 1893 attention was directed to the prolific character of the oil-bearing lands of Grozni, in the Terek district, about 500 miles north of Baku, and recent developments in this field point to the conclusion that the Grozni oil-field will be a formidable rival of those at Baku. **Production.** The production in the Grozni district during the years 1897, 1898, and 1899 has been as follows:

1897	27,568,794 poods.
1898	17,716,899 „
1899	25,194,566 „

Petroleum also occurs in many places in the Apscheron peninsula, in the Kuban district, in the Crimea, and at Petchora, in the north of Russia, near the Ural Mountains.

The Canadian Petroleum Industry.—In the Enniskillen district, in Lambton County, Ontario, petroleum has been obtained in large quantities for the past forty years. According to a statement made by the Imperial Oil Company, Limited, of Canada, the **Production in Canada.** production was as follows for the years 1898 and 1899:

District.	Barrels of 35 imperial gallons.	
	1898.	1899.
Petrolia . . .	513,179	a 528,641
Oil Springs . .	133,366	b 107,487
Bothwell . . .	66,404	65,044
Plympton . .	25,000	—
Dawn . . .	5,923	—
Euphemia . .	5,227	—
Zone . . .	901	—
Dutton . . .	—	3,622
	750,000	704,794

a. Includes production from Plympton.

b. Includes production from Dawn, Euphemia, and Zone.

Note.—The imperial gallon has one-fifth greater capacity than the American gallon. The Canadian "barrel" of 35 imperial gallons contains 2·4 cubic inches more than the United States "barrel" of 42 American gallons, so that the two units of measurement are nearly equivalent.

Other Sources.—Petroleum is largely produced in Galicia (Austria-Hungary), Roumania, and Elsass. **Galicia.** The Galician oil-belt extends for a distance of about 220 miles along the northern slopes of the Carpathian Mountains, whilst the Roumanian deposits occupy the south-eastern and southern slopes of the Southern Carpathians or Transylvanian Alps. The Galician oil-fields have been worked by means of drilled wells for many years, but it is only recently that those of Roumania have been similarly developed, though **Roumania** petroleum has long been obtained in the latter country from hand-dug wells. Owing to its favourable geographical position, and to the successful results of recent borings, Roumania seems likely to assume a position of considerable importance among petroleum-

Production in Galicia. producing countries. The production of petroleum in Galicia in 1898 was as follows:

District.	Metric centners of 100 kilos. (220·462 pounds.)
Drohobycz	2,200,780
Jasielski	966,850
Stanislau	106,870
Other districts . . .	30,010
	3,304,510

or 330,451 metric tons of 2,204·62 lbs., equal to 2,376,108 American "barrels" of 42 gallons.

Production in Roumania. The production of crude petroleum in Roumania in 1898 and 1899 was, according to the Imperial and Royal Austro-Hungarian Consulate in Ploiesti, as follows:

Locality.	Tank carloads of 100 metric centners.	
	1898.	1899.
Baicoi	340	800
Glodeni	1,925	2,300
Campina	2,650	8,500
Doftana and Bustenari .	2,730	3,860
Ochisori and Matitza .	160	380
Sarata (Buzeu) Tega	1,185	1,890
Other localities . .	1,667	2,100
	10,657	19,830

Other reports give a much larger production, trustworthy statistics being difficult to obtain.

Germany. The production of crude petroleum in Germany in

1899 amounted to 192,232 barrels. Of this, the fields of Elsass yielded 168,203 barrels, and those of Hanover 24,029 barrels. The production in Italy for 1898 was 14,489 barrels, and of this 13,734 barrels were obtained in the Province of Piacenza. In the United Kingdom petroleum has been met with only in small quantities, but, as is well known, the production of mineral oil by the distillation of shale is an important industry in Scotland, 2,137,993 tons of shale having been mined in Great Britain, chiefly for distillation, during the year 1898.

Italy.

United Kingdom.

Shale oil.

In Java the production of crude petroleum has for several years past exhibited steady progression. In Sumatra the output, which for 1899 showed a considerable falling-off from that of the previous year, has lately been largely augmented. In Borneo the recent drilling operations at Kotei have already resulted in a large production of fuel-oil, for the distribution of which adequate arrangements are being made.

Java.

Sumatra.

Borneo.

The production of the Japanese oil-fields for 1899 was reported to be about 800,000 barrels, and it is estimated to have been increased to probably as much as $1\frac{1}{2}$ million barrels for the year 1900, the chief centres of activity being in Echigo.

Japan.

In Upper Burma the primitive hand dug wells in the Yenangyaung oil-fields, which, in the days of King Theebaw, yielded the "Rangoon oil" of commerce, have long been superseded by drilled wells, and an industry of great importance has been created by the Burmah Oil Company. According to the official returns, the production in India for 1898 was 18,972,368 imperial gallons (542,068 American "barrels"), and of this Burma contributed 92 per cent., the remainder being obtained in Assam, where the Assam Oil Company has already met with remarkable success in drilling operations.

Burma.

Assam.

Peru.

The production of crude petroleum in Peru for 1899 was about 900,000 barrels.

Magnitude of industry as a whole.

It will thus be seen that the petroleum industry, as a whole, is in a condition of rapid extension, and to afford some idea of its present magnitude, it may be stated that a pipe 41 inches in diameter would be needed for the conveyance of the petroleum which the world is at present using, assuming a rate of flow of 3 feet a second; and that for the storage of a year's supply a rectangular cistern 929 feet in length, breadth, and height would be required.

CHAPTER III.

PRODUCTION, REFINING, ETC.

The petroleum well.

The United States.—The petroleum well proper is an artesian well, and the development of the petroleum industry in the United States dates from the sinking of the first oil-well of this description in 1859.

Construction of the derrick.

The first operation connected with the drilling of a petroleum well is the building of the derrick. This structure is pyramidal in form, and consists of four strong timber uprights which rest on stout wooden sills and are held together by ties and diagonal braces. The depth of the well, or, more correctly, the length of the string of drilling tools, determines the height of the derrick. In most of the principal oil-fields of the United States, where the oil-bearing rock lies at a depth of 2000 feet or more beneath the surface, it is necessary to employ long and heavy strings of tools, and consequently here the derrick is at least 70 feet in height, by about 20 feet square at the base, and 4 feet square at the summit. The upper ends of the four corner posts of the derrick are firmly held in position by a strong timber structure called the *crown-block*, which itself is surmounted by a pent roof. The floor of the derrick is slightly cambered, and the lower part of the structure is frequently boarded in. A ladder leads from base to summit of the derrick.

Walking-beam, &c.

Immediately outside the derrick, on the strong wooden foundation, stands the *samson-post*, a stout square pillar of wood, which carries the *walking-beam*.

There is a smaller upright inside the derrick, termed the *headache-post* or *life-preserver*, to support the end of the walking-beam when disconnected. The end of this beam outside the derrick is connected by means of a rod called the *pitman*, with a crank attached to the axle of the band-wheel. This wheel runs in bearings on two uprights, and is caused to revolve through the medium of a belt or band driven by a steam-engine in an adjoining shed, thus imparting a rocking movement to the walking-beam.

Steam-engine and boiler. The steam-engine is of the horizontal pattern, of 12 to 15 h.-p., and is fitted with reversing gear. The boiler is of the locomotive type, and is often fired with natural gas. To the side of the derrick opposite the samson-post are fixed the bearings of the *bull-wheel*, a wooden windlass of substantial construction, used for lowering and raising the drilling tools. The bull-wheel is driven by the *bull-rope*, a two-inch plain-laid cable, joined by iron couplings, which runs, crossed, in grooves in the bull-wheel and in the drive-wheel on the band-wheel shaft. The bull-wheel is provided with a powerful band-brake. A second and smaller windlass, called the *sand-reel*, is also provided. This windlass is used for raising the detritus and water from the well. It is fixed close to the band-wheel, and one of its supports is pivoted to the foundation of the derrick. Attached to this support is a rod which passes into the derrick, where it is connected with a vertical lever. This lever actuates a friction-clutch on the sand-reel shaft, bringing it into contact with the band-wheel and thus imparting motion. The driller can, from the mouth of the well, start or stop the revolution of the sand-reel. The *telegraph* is an endless cord passing round a pulley on the throttle-valve of the engine and a similar pulley in the derrick. The reversing-link is also operated by a cord, and the

Bull-wheel.

Sand-reel.

Control by driller.

running of the engine can thus be controlled from the interior of the derrick. The bull-wheel being driven through the medium of the band-wheel, the pitman which gives motion to the rocking-beam is disconnected when the bull-wheel is used, and similarly the bull-rope is thrown off when the pitman is in use. The cable used to support the drilling tools is a six-inch (two inches in diameter) untarred Manilla rope. It passes from the great windlass over a grooved wheel, termed the *crown-pulley*, fixed in the crown-block at the summit of the derrick, and thence to the drilling tools. **Drilling cable.**

The principal tools used in drilling are: **Drilling-tools.**

Rope-socket.
Sinker-bar.
Jars.
Auger-stem.
Bit.

The *jars* may be likened to a couple of elongated and flattened links of a chain constructed to slide freely within each other. This device was invented in 1831 by William Morris, and its function is to give the drill a sharp jar on the upward stroke, thus loosening the bit if it has become jammed in the rock. **Jars.**

The jars practically divide the string of tools into two sections, the one delivering a blow downwards and the other a blow upwards. The *auger* or *drill*, which cuts and pulverises the rock, consists of the bit, or cutting tool, the auger stem to provide the necessary weight, and the lower link of the jars. The *sinker-bar* and upper link of the jars provide the necessary momentum for delivering an upward blow on the inside of the lower link of the jars. Besides bits of various sizes, the necessary outfit includes *reamers* to enlarge the bore of the well, *winged substitute* placed above the bit to keep it from glancing **Auger or drill.** **Sinker-bar.** **Reamers, &c.**

off, *larger jars*, *temper screw*, and *clamps*, *wrenches*, **Bailer.** *sand-pumps* to remove the detritus, and *bailer* to **Temper-screw.** remove water from the well. The temper-screw hangs from a hook on the end of the walking-beam over the mouth of the well, and its function is to provide for the gradual lowering of the tools as the drilling proceeds. At the lower end of the temper- **Clamps.** screw are the clamps, which can be screwed together so as to grasp the drilling cable at the required point. **Sand-pump.** The sand-pump is frequently a plain cylinder of galvanised iron, about 6 feet or more in length, provided at the bottom with a valve opening inwards. This valve has a stem projecting downwards so that when the empty cylinder is lowered to the bottom of the well, the valve opens, allowing detritus to enter, and again, when withdrawn from the well and lowered into a trough, the opening of the valve permits the contents to escape. The valve, of course, closes by gravitation as the cylinder is raised from the well. Another form of sand-pump has, in addition to the bottom valve, a plunger attached to an iron rod passing through a stirrup spanning the top of the cylinder. This apparatus is suspended from the upper end of the plunger-rod, and when it reaches the bottom of the well the slackening of the rope allows the plunger to descend to the bottom of the cylinder. When the rope is tightened the plunger is first raised, thus facilitating the entrance of the detritus. When the plunger has reached the stirrup the cylinder itself begins to rise. The rope to which the sand-pump is attached passes over a small pulley at the top of the derrick and thence to the sand-reel. The bailer, which is used to remove water or oil from the well, is constructed similarly to the simpler form of sand-pump, but is **Fishing-tools.** much longer. Besides the drilling tools it is necessary to provide a number of appliances termed *fishing-tools*.

These, as their name implies, are for the recovery of drilling tools which may have been lost in the well, and their forms necessarily vary considerably.

Drilling a well. The first step in the drilling of a well is to sink a conductor through the surface ground to the solid bed-rock. When the superficial clays and gravels are not more than 10 to 15 feet in thickness, a common well-shaft, 8 to 10 feet square, is dug to the rock, and a wooden conductor, somewhat greater in internal diameter than the proposed bore of the upper part of the well, is placed so as to extend from the surface of the rock to the floor of the derrick, the gravel and mud being kept out of the well by a carefully-made joint between the rock and the conductor. When the depth of superficial soil is too great to admit of digging down to the rock, strong iron piping, called *drive-pipe*, furnished at the lower end with a sharp-edged shoe, is forced down by means of a mall working in guides, as in pile-driving.

Conductor.

Drive-pipe.

If the bed-rock is reached at a less distance than about 60 feet from the surface, the drilling tools cannot at first be used in the ordinary manner, and the drilling has then to be commenced by the operation termed *spudding*. In this operation the cable by which the drilling tools are suspended is coiled two or three times round the axle of the revolving bull-wheel, the end being held by the driller; or the cable is attached to the crank of the band-wheel through the medium of what is known as a *jerk-rope*. In either method the cable is alternately tightened and slackened. When a sufficient depth is reached to admit of the regular use of the drilling tools, the cable is properly coiled on the bull-wheel axle, the bull rope is thrown off, the pitman connected with the crank, and the string of tools lowered to the bottom of the well. The jars having closed by the slackening of the cable,

Spudding.

Use of drilling tools.

the slack is taken up by turning the bull-wheel by hand until the cross-heads of the jars come together. A few inches of cable being then paid out, and the temper-screw suspended from the walking-beam being screwed home, the cable is grasped by the clamps at the lower end of the temper-screw; sufficient cable being then uncoiled from the bull-wheel, the tools are suspended from the walking-beam, and upon the beam being set in motion the tools at once begin to rise and fall, the rate of movement being so timed that the drill delivers forty or fifty blows a minute. As the drilling proceeds, the driller, who has his hand on the temper-screw lever, gives the cable a slight twist, and thus causes the chisel-end of the bit to do its work evenly over the entire surface of the bottom of the well. From time to time it is necessary to draw the string of tools up into the derrick either for the purpose of "dressing" the bit, which consists in heating the cutting end in the forge-fire and hammering it out to a blunt edge of the required width (the object of "dressing" is to preserve the width of the bit, as this determines the diameter of the well); or it may be needful to remove the detritus from the well by means of the sand-pump. At night the derrick is lighted by a primitive form of lamp burning crude oil. The operation of drilling is conducted day and night, but very seldom proceeds long without some accident necessitating the use of fishing-tools. Sometimes the fishing operation is unsuccessful, and wells have been abandoned after months of labour with the string of tools still in the hole.

Rate of movement.

"Dressing" the bit.

Sand-pumping.

Work continuous.

Fishing.

Casing the well.

As the drilling progresses the bore-hole has to be lined with artesian casing, in order in the first place to exclude the water met with in the upper strata and afterwards to prevent caving. The casing is added in successive lengths screwed together. The exclusion of

water is effected by seating the lower end of the casing on a hard and impervious stratum lying below the water-bearing formation, or by means of one of the various forms of "packer" designed to close the annular space between the casing and the bore-hole. When this has been effected a second string of casing is placed within the first, the drilling being continued through the second string, and as each string can usually only be lowered to a moderate depth, the finished well frequently contains several strings, each extending from the surface. As an illustration of the sizes and lengths of casing which may be employed the following particulars are given:

Exclusion of water.

Sizes and lengths of casing.

682 feet of 10-inch
1,060 „ „ $7\frac{5}{8}$ „
1,750 „ „ $5\frac{5}{8}$ „
} internal diameter.

On completion the well is usually "torpedoed," with the object of increasing the yield of oil. The torpedo consists of a charge of nitro-glycerine in a suitable "shell" which is lowered to the oil-bearing level and there exploded.

"Torpedo-ing" the well.

The great majority of wells in the United States do not flow, and the oil has to be raised to the surface by a pump. The arrangement employed for this purpose consists of a lift-pump attached to the lower end of a string of two-inch tubing extending to the bottom of the well, the sucker being connected with the walking-beam by a string of wooden rods passing up through the tubing. In some cases wells which would not ordinarily flow can be made to do so by confining the gas which would otherwise issue with the oil.

Pumping from well.

Before the completion of the drilling of the well, a circular wooden tank is erected to receive the oil. Such tanks commonly hold about 250 barrels, but some are of two or even three times that capacity. As soon

Receiving-tank.

as the well commences to yield, either by flowing or by being pumped, notice is given to a representative of the transportation and storage company, who connects the tank with the company's mains, by means of a two-inch pipe. When the tank is full the quantity of oil is gauged by the company, 3 per cent. is deducted for "shrinkage," or loss in transportation; one-eighth or other agreed proportion is appropriated to the land-owner; the remainder is entered to the credit of the producer in the books of the company and a certificate for this quantity is given to the producer. In the early days of the petroleum industry in the United States, the only method of transporting the oil from the well was to place it in oak barrels holding from forty to fifty gallons, and to convey these barrels by road to Oil Creek, where their contents were emptied into barges holding about 2000 barrels. The navigation of Oil Creek was not ordinarily possible and was at all times attended with great risk, and much oil was lost through barges coming into collision. This method of transportation, in default of a better, continued until the latter part of the year 1862, when a branch of the Atlantic and Great Western Railway was carried into the oil regions, and at a later date the Allegheny Valley Railway was opened from Oil City, at the mouth of Oil Creek, to Pittsburg, and a number of narrow-gauge railways were constructed as feeders. Crude oil was at first conveyed by rail in barrels coated internally with glue, but the small quantity of water present in the oil was found to dissolve the glue and cause the barrels to leak. To remove this difficulty and to reduce the cost of handling the oil, tank waggons, consisting of two wooden tanks placed on an ordinary truck, were introduced in 1865–6. These early tank-waggons held from 2000 to 4000 gallons. In 1871 a tank-car similar to those now employed was introduced.

Transportation and storage company.

Pipe-line certificate.

Early method of transport.

Beginning of railway transport.

Early tank-waggons.

This consists of a horizontal cylindrical tank of boiler-plate, lying upon a truck and furnished with a dome such as a horizontal steam-boiler has. The tank is provided with an orifice in the top of the dome for filling, and with a valve beneath, by which it can be emptied. The tank now employed is about 24 ft. 6 in. in length by 5 ft. 6 in. in diameter, and holds nearly 4500 American gallons (3748 imperial gallons). Tank barges, 130 ft. in length by 22 ft. beam and 16 ft. in depth, divided into eight compartments by oil-tight bulkheads, have been largely employed for the conveyance of oil on the Allegheny river.

Modern tank-car.

Tank barges.

The credit of having first suggested the laying of a pipe-line appears to belong to General Karns, but Mr. Hutchinson was the first to carry out the idea. Hutchinson's pipe, however, was so defectively constructed as to be useless. The first successful pipe-line was probably the one laid by Van Syckle, of Titusville, in 1865, and was four miles in length. It was not until 1875 that a trunk-line was laid. This extended from the lower oil country to Pittsburg, a distance of 60 miles, and was four inches in diameter As the refining trade developed it became concentrated on the Atlantic seaboard and the shores of Lake Erie, the transportation of the crude material to the refineries thus becoming a business of great importance, and from 1878 to 1881–2 the construction of trunk-lines was continuous. The pipe used in these trunk-lines is made specially, and is of wrought-iron, lap-welded. It is tested to a pressure of 1500 lbs. per square inch, the working pressure being 900 to 1200 lbs. or even more. The pipe is in lengths of 18 ft., provided at each end with coarse and sharp taper threads, nine to the inch, and the lengths are connected with long sleeve-couplings, also screwed taper. The line is usually laid two or three feet below the surface

First pipe-line.

First trunk-line.

Concentration of refining on Atlantic and Lake Erie.

Pipe for trunk-lines.

of the ground, although in some places it is exposed, and at intervals bends are provided to allow for expansion and contraction. At the pumping-stations there are tanks of boiler-plate, usually about 90 ft. in diameter, by 30 ft. in height, the oil being pumped from the tanks of one station to those of the next, though sometimes a loop is laid round a station, and the oil has thus been pumped a distance of 110 miles with one engine. Worthington pumping-engines, from 200 to 800 h.-p., are employed. These pumps have independent plungers, with exterior packing, valve-boxes subdivided into small chambers and leather-lined metallic valves with low lift and large surfaces; they are so constructed that before one plunger has completed its stroke another has taken up the work, thus keeping the column of oil in continuous motion. The pipe-lines are cleared of obstructions caused by sediment deposited by the oil, by the use of an ingenious instrument termed a "go-devil." This apparatus consists of a conical brush of steel wire furnished at the base, or rear end, with a leather valve in four sections, strengthened with brass plates and with steel wire guides. The "go-devil" is pumped through with the oil, and travels at about three miles an hour. Its progress can be traced by the scraping sound emitted, and it is followed from one pumping-station to another by relays of men, who must not allow it to get out of hearing, otherwise, in the event of its progress having been arrested by an obstruction, it may be necessary to take up a considerable length of piping to ascertain its position. The oil is pumped into storage tanks, which are usually 93 ft. in diameter by 30 ft. in height, have slightly conical wooden roofs covered with sheet-iron, and hold 35,000 barrels each.

Tanks.

Pumping-engines.

"Go-devil" for clearing pipe-lines.

Russia.—In the drilling of petroleum wells in the Baku district and other parts of Russia, derricks and

drilling tools presenting a general similarity to those already described are employed, but in many cases a string of iron rods takes the place of the drilling cable. These rods are from 40 to 60 ft. in length, and are screwed together, an additional rod being added from time to time as the drilling proceeds. This system is by some considered preferable to the American, especially when the strata to be drilled through lie irregularly, but it is, undoubtedly, far less expeditious, as considerable loss of time is involved in unscrewing the rods when the tools are required to be raised from the well. The Russian wells are of much greater diameter than those in the United States, a commencing diameter of 26 inches or more being now not unusual, and are ordinarily lined with riveted casing, but as such casing is found to imperfectly exclude water, screwed artesian casing is now used for the smaller sizes. Owing to the large quantity of sand which is mingled with the oil, it is impossible to use ordinary pumps in the wells, and when the wells do not flow the oil is raised by a bailer, similar to the sand pump or bailer already described as in use in the United States, but of larger size.

Iron rods in lieu of cable.

Rod system less expeditious.

Wells of greater diameter.

Casing.

Oil raised by bailer.

REFINING.

The stills usually employed in petroleum refineries are of horizontal cylindrical form, constructed of boiler-plate, and surmounted by a dome furnished with a vapour-pipe. These stills, which may be 30 ft. in length by $12\frac{1}{2}$ ft. in diameter, but are sometimes smaller, are set in brickwork furnaces, and are heated by solid or liquid fuel. When the crude oil in such a still is subjected to gradually increasing heat, the constituents are successively converted into vapour, substantially in the order of their volatilities, though

Size of stills.

Process of fractional distillation (intermittent).

the separation thus effected is by no means perfect, as the oils of higher boiling-point are to some extent carried over by the vapour of those of lower boiling-point. The vapourised oil passes through the vapour-pipe of the still into the condenser, which may consist of an iron pipe or series of pipes surrounded by cold water, and is thus brought again into the liquid condition. In this way any desired classification of the products may obviously be effected.

Condenser.

The process described, in which the still is periodically refilled, is known as the "intermittent system of fractional distillation," and is that which is always adopted in the United States. On the other hand, in Russia what is known as continuous distillation is employed. This involves the use of a series of stills heated to successively higher temperatures, which are carefully maintained, and the crude oil is caused to flow slowly and continuously through the whole series, being thus subjected to a steadily increasing heat while the temperature of the contents of each still remains practically constant. In this manner each still yields a product of given volatility corresponding with the temperature at which it is maintained. The loss of time, waste of fuel, and injury to plant involved in cooling down and re-heating the stills in the intermittent system are thus avoided.

Continuous distillation.

Division of distillation.

In practice it is usual to divide the distillation into two operations, the more volatile products, petroleum spirit and kerosene, being obtained in the first, and the residue being transferred to other stills to be heated to a higher temperature with the object of separating the lubricating oils, &c.

Tail-house.

The condensing arrangement terminates in what is known as the *tail-house*, where provision is made for diverting the stream of distillate into various tanks. The products, thus classified in accordance with in-

dustrial requirements, are usually purified by treatment successively with sulphuric acid and a solution of caustic soda, followed by washing with water; but when the crude oil contains sulphur a special process is also adopted to remove this impurity. The lubricating-oil distillates yielded by petroleum containing solid hydrocarbons are subjected to a low temperature, when the paraffin crystallises and is separated from the oil by means of filter-presses and hydraulic presses. The paraffin is refined by treatment with animal charcoal, and may be thus rendered colourless, odourless, and tasteless.

Chemical treatment.

Paraffin separation.

It will readily be understood that this is but a mere outline of the process of refining, but it will suffice to give a clear indication of the principle upon which the refiner converts the raw material into the products met with in commerce. Information respecting the character of these products will be found in the following chapter.

Process merely outlined.

The manufacture of shale-oil carried out in Scotland commences with the destructive distillation of the shale, crude oil and ammonia being obtained in this operation. The crude oil, amounting to about thirty gallons from the ton of shale, is fractionally distilled in substantially the same manner as the petroleum, continuous distillation being adopted; but, in consequence of the comparatively complex composition of the shale-oil, the operations, though similar in principle to those of the petroleum refiner, are less simple, at least two distillations being requisite to effect the desired separation of the products.

Scottish shale-oil industry.

MARINE TRANSPORT.

The building of tank steamships for the marine transport of petroleum has steadily progressed, and

Tank steamers.

every recent year has seen important additions to the fleet of these vessels, some of those recently launched having a carrying capacity of as much as 8500 tons.

Principles of construction. The essential features of construction of tank steamers are:

(1) Provision for the expansion of the oil under an increase in temperature.

(2) Provision for keeping each tank full by automatically supplying any loss due to leakage or to contraction consequent upon a fall in the temperature of the oil.

(3) Provision for the escape of the gases given off by the oil.

(4) Special precautions to prevent the passage of any oil into the boiler space.

Isolating coffer-dams. The engines and boilers are placed either amidships or at the after end of the vessel, being in either case separated from the oil-space by coffer-dams. In the former method of construction the oil-tanks are both forward and aft of the machinery space, and the screw-shaft is carried through the after tanks in a tunnel.

Division of oil-tanks. The oil-tanks are subdivided by transverse bulkheads, and by an amidships fore and aft bulkhead, the sides of the tanks being formed by the skin of the ship.

STORAGE AND DISTRIBUTION.

Ports of discharge in the United Kingdom. The kerosene imported into Great Britain and Ireland from the United States and Russia in bulk is landed at the ports of London, Liverpool, Manchester, Barrow, Bristol, Cardiff, Shields, Sunderland, Hull, Plymouth, Dublin, and Belfast.

London Wharves. In London the principal wharves are at Purfleet, Thames Haven, Millwall, and Beckton on the Thames, and at Bromley and Bethnal Green on the Lea Cut and Regent's Canal respectively. The tank steamers discharge direct into

the storage-tanks at Thames Haven, Purfleet and Beckton, and tank barges are employed for the landing of the oil at the other wharves named, the steamers lying, during the discharge, at moorings in the Thames at Greenwich and Blackwall. There are also smaller storage installations at Hammersmith, Battersea, Fulham, Camberwell, Hampstead, Camden Town, Bow, Deptford and Greenwich, and there are many still smaller tank depôts at railway stations and elsewhere to facilitate the distribution of the oil carried by barges and tank railway-waggons. The larger storage installations are provided with vertical cylindrical iron or steel tanks, placed on the ground, but surrounded with a moat formed by embankments or walls, of a capacity equal to that of the tanks enclosed. These tanks are usually from about 40 to 70 ft. in diameter, by about 25 to 30 ft. in height, but in some instances are as much as 90 ft. across. The largest hold over one million imperial gallons, each inch of depth being equivalent to about 3300 gallons. Some of the tanks have a flat top with a raised edge forming a receptacle for water, and others a slightly domed top. At the distributing stations on the railways, horizontal cylindrical tanks are employed.

Smaller storage installations.

Storage arrangements.

At Liverpool, the Mersey Docks and Harbour Board have erected, in the neighbourhood of the Herculaneum Dock, a number of vertical cylindrical tanks, of about 2000 to 3000 tons capacity each, into which the tank steamers discharge direct through an 8-inch pipe-line. There are similar installations on the Ship Canal, Manchester, and at the other ports already named.

Installations at Liverpool and Manchester.

Comparatively little kerosene is now landed in barrels. Lubricating oils are imported in bulk from Russia, but from the United States have until quite recently been wholly brought in barrels.

Under the regulations made by the Thames Conser-

Petroleum spirit landed at Thames Haven, for London.

vancy, petroleum spirit, which is brought into the port of London in barrels from the United States, is landed at Thames Haven. Provision for the storage of petroleum spirit in barrels is also made at the ports of Liverpool and Bristol.

Gas-oil.

Gas-oil, which is imported in bulk, is to a large extent delivered direct from the steamer to the works of the gas companies, where it is stored in tanks of the usual construction.

Bulk distribution of kerosene.

Kerosene is largely conveyed in bulk from the main storage-installations by rail in tank-waggons, or in some instances by tank-barges on the canals, to subsidiary storage-depôts, and is thence distributed to the retailers in the road tank-waggons with which readers of this book are familiar. In this manner most of the burning oil from the refineries of the United States and Russia now reaches the retail dealer without the employment of the barrel, in which delivery was formerly made.

CHAPTER IV.

COMMERCIAL PRODUCTS OF PETROLEUM, SHALE-OIL AND COAL-TAR.

Nature of crude petroleum. CRUDE petroleum, as it comes from the well, is an oily liquid varying in physical and chemical characters in different districts and countries, and at different depths in the same district. It is usually of a brown colour by transmitted light, but by reflected light commonly exhibits a green colour. **Colour.** Some descriptions are, however, so dark in colour as to appear black unless viewed in a thin stratum, and, on the other hand, crude oil is occasionally met with of a pale yellow colour. **Odour.** The odour of crude oil of good quality is generally considered not unpleasant, but when sulphur compounds are present in the oil the odour may be most offensive. Crude petroleum is nearly always lighter than water, its **specific gravity**, according to the authors' experience, lying between the extremes of ·771 and 1·020 (water = 1·000), but being usually a little below ·800 to less than ·900. **Inflammability.** The lighter descriptions are highly inflammable, and very freely give off vapour, not only at ordinary temperatures, but even when cooled to zero Fahrenheit.

Chemical composition. Crude petroleum may be described as a complex mixture of hydrocarbons (compounds of carbon and hydrogen), ranging from the gaseous (for some descriptions of American petroleum evolve gas which has been held in solution) to the solid (paraffin wax), and we have seen in the previous chapter that the first object

of the refiner is to separate these hydrocarbons by fractional distillation, and group them in such proportions as to give the desired commercial products. Petroleum also frequently contains sulphur (as already mentioned), oxygen, and nitrogen.

Division into commercial products.

"Naphtha."

By distillation Pennsylvania petroleum yields from 8 to 10 per cent. of "naphtha," from 70 to 80 per cent. of "refined oils," and from 5 to 9 per cent. of "residuum," the loss being about 5 per cent. The naphtha, on being re-distilled, may be divided into "gasoline" and the various other less-volatile products hereafter described, but gasoline itself is sometimes further subdivided into "cymogene," "rhigolene," and "gasoline."

"Gasoline."

"Cymogene."

"Rhigolene."

Cymogene boils at 32° F., and can, therefore, only be preserved in a liquid state in a freezing mixture or under pressure, whilst rhigolene has a boiling-point of 65° F. These liquids, which have in admixture a specific gravity of ·636, are used for surgical purposes as a local anæsthetic. A highly volatile product, of specific gravity ·625, obtained from gasoline, has long been employed for the same purpose in admixture with sulphuric ether. The generic term of "petroleum ether" is applied to the product in question (not the mixture), but various other descriptions of "petroleum ether" made in this country are, as will be seen from the particulars subsequently given, of higher specific gravity and lower volatility.

Light gasoline.

Gasoline, the specific gravity of which usually ranges from ·642 to ·648, is used to carburet air, in what are known as air-gas machines, for burning as an illuminant, and is also largely employed as fuel in cooking-stoves in the United States.

"680 spirit," "petrol," motor-car spirit.

A product, known formerly as "boulevard gas-fluid," with a specific gravity of about ·680, has for a long time been burned in the United States in street naphtha lamps. A similar spirit, to which the makers gave the name of "petrol," has been manufactured for many years in this

country, and in common with "·680 spirit" or "76° spirit" (its density being about 76° on the Baumé scale) of American manufacture, is largely used as a source of power in the internal-combustion engines of automobile vehicles, and as a fuel in steam motor-cars of a certain type. "Deodorised naphtha," or "benzoline,"* which has a specific gravity of about ·700, is also used in motor-cars, as well as for detergent purposes (in the process known as "dry-cleaning"), and as a source of light in sponge-lamps (lamps containing an absorbent material). By careful fractionation, various descriptions of "petroleum ether," of which the following are examples, are manufactured in this country from deodorised benzoline (boiling-point, say, 130° to 350° F.):—(1) Specific gravity ·630, boiling-point 82° to 142° F.; (2) specific gravity ·640, boiling-point 89° to 145° F.; (3) specific gravity ·667, boiling-point 128° to 198° F. (used for extracting resins, &c.); (4) specific gravity ·689, boiling-point 130° to 212° F. (for "denaturing" alcohol); (5) specific gravity ·703, boiling-point 176° to 240° F. (for extracting gums, &c.); (6) specific gravity ·725, boiling-point 212° to 270° F. (for extracting fats); (7) specific gravity ·730, boiling-point 220° to 290° F. (for extracting fats). The commercial pentane made in this country for use as a standard of light in photometric work has a specific gravity of about ·625 (·623 to ·626) and a boiling-point of 76° to 128° F. The boiling-points given in the preceding two paragraphs are those obtained with a thermometer having its bulb immersed in the liquid, the higher temperature being that at which the volatilisation of the contents of the retort is completed. Finally, the naphtha yields, as the least volatile of the products,

"Benzoline."

"Petroleum ether."

Pentane.

* The term "prime city naphtha" is sometimes applied in the United States to the crude naphtha or benzoline which has not been submitted to the deodorising treatment.

"Benzine." "benzine," of a specific gravity of about ·730, which is largely employed in "dry cleaning" as well as in oil-cloth and varnish making.

"Refined oil." The "refined oil" obtained from American petroleum is of several descriptions, but only two of these, "Ordinary" and "water-white," or high-test, American. the ordinary American lamp-oil of commerce, and what is known as "water-white," or "high-test," oil, are imported into this country. The ordinary oil is usually of a pale straw colour, and has a specific gravity of about ·796. Its flash-point is generally not much above the legal limit of 73° F. (Abel test). The higher grade of oil, of which the average crude petroleum yields only about 15 or 16 per cent., is colourless, or nearly so, and has a specific gravity of about ·788. Its flash-point is over 100° F. (Abel). There is also manu-Mineral colza-oil. factured to a small extent a burning oil having a specific gravity of ·825 to ·830 and a flash-point of about 250° F. (Abel). Of this oil, which is known as *mineral colza* or *mineral sperm* or *mineral seal oil*, about 10 per cent. may be obtained from the crude petroleum.

Gas-oil, lubricating oils, vaseline and paraffin from residuum. The "residuum" already referred to yields, on further distillation, "intermediate oil," or "gas-oil" (used as a source of gas for illuminating purposes), a series of lubricating oils of gradually increasing specific gravity, viscosity, and flash-point, vaseline, and solid paraffin or paraffin-wax.

Russian petroleum products. The parallel products manufactured from Russian (Baku) crude petroleum are of somewhat different character. This description of petroleum yields, according to the district in which it is obtained, from "Benzine." 2 to 10 per cent. of "benzine" (also termed light Kerosene. petroleum), from 27 to 40 per cent. of kerosene (burning oil), 4 per cent., or more, of the lighter description of "solar oil" for use in lamps, and from 50 to 60 down "Astatki." to 35 or 36 per cent. of "astatki" (residue). The benzine (sometimes divided into "light" and "heavy")

has a higher specific gravity than the corresponding product obtained from American petroleum, but the boiling-point is not proportionately higher. The kerosene usually has a specific gravity of ·825 and a flash-point of about 85° F. (Abel). A small quantity of high-test kerosene, having a specific gravity of about ·823 and a flash-point of about 100° F. (Abel), is also made. The solar oil has a specific gravity of about ·865 and a flash-point of about 250° F. (Abel). A small proportion of the astatki is further distilled, with the object of obtaining solar-oil distillate, specific gravity about ·875 and flash-point about 240° F., for use in gas-making, and a series of lubricating oils (the crude oil contains scarcely any paraffin), but by far the greater part of it is employed as liquid fuel, for which there is so great a demand in Russia that the astatki is really the principal product, the refiner now seeking to make as much of this and as little of the other products as possible, consistently with the separation of sufficient of the more volatile constituents of the crude oil to give the astatki the requisite flash-point.

"Ordinary" and "high-test" kerosene.

Light solar oil.

Solar oil distillate (gas-oil), and lubricating oils.

Astatki the principal product.

From the Eastern Archipelago petroleum spirit (benzine), gas-oil, and fuel-oil have already been brought in some quantity to this market. The gas-oil has a specific gravity of about ·890 and a flash-point ranging from 120° to 150° F. (Abel), whilst the fuel-oil has a specific gravity of about ·970 and a high flash-point.

Gas-oil and fuel-oil from Eastern Archipelago.

As a commencement has already been made by Roumania in contributing supplies of petroleum products to the markets of the United Kingdom, it may be well to mention that the crude oil of that country resembles American rather than Russian (Baku) petroleum. The products which have already been imported are kerosene, specific gravity about ·810 and flash-point 74° F. (Abel), and gas-oil, specific gravity about ·865

Roumanian petroleum products.

Kerosene and gas-oil.

and flash-point ranging from 110° to 140° F. (Abel). A shipment of the crude oil has also been made to London.

There is at present no prospect of liquid petroleum products being imported into the United Kingdom from countries other than those mentioned, so that no specific reference to the characteristic features of the oils of those countries is needed here.

Scottish shale-oil products.

Allusion to the Scottish shale-oil trade has been made in previous chapters. The oil-shales of Midlothian and Linlithgow yield, by destructive distillation at a bright-red heat, about 30 gallons to the ton of mineral oil (besides ammonia), and this oil furnishes on fractional distillation a series of products resembling those obtained from petroleum.

Crude shale-oil.

The crude shale-oil has a specific gravity of ·860 to ·890, and frequently is solid at temperatures below 90° F. owing to the large amount of paraffin which it contains.

"Gasoline" and "naphtha," burning oils, gas-oil, lubricating oils and paraffin.

It yields from 3 to 6 per cent. of "gasoline" and "naphtha," about 30 per cent. of burning oils (for use in lamps), about 9 per cent. of gas-oil, about 20 per cent. of various lubricating oils, and about 10 per cent. of paraffin. The burning oils have a specific gravity of about ·810 and a flash-point of about 105° F. (Abel).

Brown-coal and peat products.

In Saxony similar products are obtained from lignite or brown-coal, but these are not imported into the United Kingdom. Peat of good quality yields by destructive distillation from 3 to 6 per cent. of tar, from which burning oil, lubricating oil and paraffin can be obtained, but the attempts which have been made to carry out the process on a commercial scale have not been successful.

Coal-tar and coal-tar products.

The coal-tar of gas-works is a black, more or less viscid liquid, of characteristic odour, of specific gravity usually between 1·1 and 1·2, and may be described as an extremely complex mixture of various hydrocarbons,

together with chemical compounds of carbon, hydrogen, oxygen, sulphur and nitrogen. It is employed in the crude state as a coating to protect or preserve wood, stone, brick-work and iron, and is largely used in the manufacture of roofing-felt. It is, however, chiefly of value as a source of benzol, anthracene, carbolic acid and other products. The tar may by a preliminary distillation be separated into four fractions, the first consisting of "crude benzol" and "naphtha," the second of "carbolic oil," the third of "dead oil" (so called because it sinks in water), and the fourth of "anthracene oil," the residue constituting "pitch." The two earlier fractions are re-distilled, the first yielding "benzol" (benzene, toluene and xylenes), from which after nitration and subsequent conversion into aniline, &c., artificial colouring matters are obtained, "solvent naphtha" employed in dissolving caoutchouc (india-rubber) for the manufacture of water-proof materials, &c., and for "dry-cleaning," and "heavy solvent naphtha," also known as "burning naphtha," largely used for making anti-fouling compositions for ships' bottoms, and in admixture with petroleum spirit for burning in "flare-lamps"; the second furnishing, upon further treatment, liquid and solid carbolic acid and naphthalene, both of which are employed in the artificial-colour industry, the former also very largely for antiseptic purposes in surgery, as a disinfectant for household purposes and for the manufacture of picric acid, whilst the latter in addition serves as an enricher of illuminating gas and as a substitute for camphor in preventing the ravages of insects in woollen goods and furs. The third original or main fraction, also called "creosote oil" or "heavy oil," which has a greenish-yellow colour, due to fluorescence, but by transmitted light is dark-red, is chiefly used in the creosoting of timber. The fourth original fraction

Distillation. **Benzol.** **Solvent naphtha.** **Burning naphtha.** **Carbolic acid.** **Naphthalene.** **Creosote oil.**

Anthracene. Pitch. yields anthracene, from which alizarine and other coal-tar colours are produced. The pitch is employed in street-paving, as well as in the manufacture of paints or varnishes, patent fuel (briquettes), roofing paper, &c.

Proportion of products. The proportions of the various products depend to a considerable extent upon the quality of the tar and the method of treatment adopted, of which the foregoing is merely an illustrative outline. The first original fraction may, however, be considered to represent 2·2 per cent. of the tar by weight, the second 10·6, the third 7·6, the fourth 16·9, and the pitch 60·5 per cent.

Production of coal-tar. Mr. Lewis T. Wright estimated that the amount of coal-tar produced and consumed in the United Kingdom in 1885 was 105,625,000 gallons, of which about 7½ per cent. was used for tarring, asphalting, &c., and about 1 per cent. for retort-firing, so that 97,175,000 gallons went into the distiller's hands.

Tar from coke-ovens, &c. Tars obtained from coke-ovens, gas-producers, and blast-furnaces (those in which the fuel used is coal), present, in some instances, essential differences from the tar of the gas-works, owing to the lower temperature at which they are obtained, and such tars are of less value.

India-rubber solution, and paints containing petroleum. The Petroleum Acts have been held to apply to substances containing "petroleum," such as paints and varnishes and india-rubber solution, and accordingly inspectors under the Acts may have occasion to subject such substances to the test prescribed. Liquid "paint-dryers" and turpentine-substitutes may also be found to come within the provisions of the Acts.

Paint dryers, &c.

Classification of petroleum, shale-oil and coal-tar products. In the following statement an attempt has been made to classify the various products of petroleum, shale-oil, and coal-tar met with in commerce in this country, to indicate their salient characteristics with a view to their identification, and to give the various names under

which they are sold. It may here be remarked that, on the whole, the commercial nomenclature of the more volatile products is vague and somewhat confusing.

PETROLEUM PRODUCTS.

PETROLEUM SPIRIT.	PENTANE .	Used as a standard of light in photometric work. Specific gravity ·625. Boiling-point 76° to 128° F.
	GASOLINE .	Distinguished as ·650 gasoline. Formerly also called "canadol" in the United States. Specific gravity usually ·642 to ·648. Boiling-point, say, 90° to 200° F.
	PETROLEUM ETHER .	At one time sold as "Sherwood oil" in the United States. For particulars of various descriptions of petroleum ether made in this country, see pp. 56 and 57.
	680 SPIRIT	Also known as "·680 or 76° (that being the density on the Baumé scale) gasoline," "motor spirit," or "motor-car spirit," "petrol,"* "motorine," "carburine," and (in the United States) "boulevard gas fluid." Specific gravity ·680 (hence the name). Boiling point, say, 120° to 250° F.
	BENZOLINE	Also termed "ordinary spirit" or "naphtha" when in the condition of the untreated distillate, and "deodorised spirit" when purified. Sometimes termed "city naphtha" in the United States. Also in that country known as "naphtha," and formerly as "Danforth's oil," when of a specific gravity of ·690 to ·700. Specific gravity ·700. Boiling-point, say, 130° to 350° F.
	LIGROÏNE .	A term which has been applied to a product of specific gravity about ·715, and boiling-point 194° to 248° F., as well as to one of lower specific gravity.
	BENZINE .	Specific gravity ·730 to ·750. Boiling-point, say, 248° to 302° F. This liquid must be distinguished from the coal-tar product benzene (benzol).†

* Petrol is also made for motor-car use of specific gravity ·700.

† A description of benzine (cleaning benzoline) of specific gravity ·703 is used for glove-cleaning, &c.

Note.—The foregoing products, as met with in this country, are made from American petroleum, either in the United States or here. The parallel products from Russian petroleum are not imported, but as already mentioned benzine has been brought to the United Kingdom from the Eastern Archipelago. The whole of the products have flash-points far below the legal standard of 73° F., and most of them evolve vapour freely even at a temperature of zero Fahrenheit. They are therefore highly inflammable. Particulars of various industrial uses of petroleum spirit in this country will be found in Appendix XV.

PETROLEUM OIL. Also known as "refined petroleum," "petroleum" (in Russia), "kerosene," "crystal oil," "paraffin oil" (though this name is properly applied only to the shale-oil product). Also formerly termed "photogene." Two distinct classes of oils in this category are imported from the United States, and two from Russia. The general use of the names already given may be said to be confined to what may be termed the ordinary American product, which has a specific gravity of about ·795 and a flash-point ranging from 73° F. (Abel) to a few degrees above, and the ordinary Russian product, the specific gravity of which is about ·825 and the flash-point about 85° F. (Abel). These oils are often sold under proprietary names or brands, such as "Tea Rose," "Royal Daylight" and "Bear Creek" (American) and "Star and Crescent" and "Syringa" (Russian). The high-test American oil is known as "water-white oil" or by the brands of "White Rose" and "Snowflake." It has a specific gravity of about ·788 and a flash-point above 100° F. (Abel). The high-test Russian oil, sold under the brand of "Testefas," has a specific gravity of about ·823 and a flash-point of about 100° F. (Abel). An oil for use in lighthouses, &c., is imported from the United States under the name of "mineral colza oil," or "mineral sperm oil" or "mineral seal oil." It has a specific gravity of ·825 to ·830, and a flash-point of 250° F. (Abel). A corresponding product for use in lamps has been imported from Russia under the names of "pyro-naphtha" and "solar oil." The specific gravity is about ·865 and the flash-point about 250° F (Abel). Very large quantities of solar-oil distillate

are shipped from Russia to the gas companies in this country for use in the manufacture of carburetted water-gas. This distillate has a specific gravity of about ·875 and a flash-point of about 240° F. (Abel). The gas-oil imported from the United States has a specific gravity ranging from ·850 to ·860 and a flash-point usually above 100° F. (Abel). *Paraffinum liquidum* is a colourless and inodorous oil, of specific gravity ·880 to ·885, used for pharmaceutical purposes, and "mixing oil" is a less highly purified product, of similar specific gravity, which is mixed with other oils for certain purposes.

LUBRICATING OIL.

Of mineral oils for lubricating purposes, imported from the United States and Russia, an extensive series is met with in commerce under the names of "spindle oil," "engine oil," "summer dark oil," "winter dark oil" (the latter bearing exposure to a low temperature without losing its fluidity), "cylinder oil," "valve oil," &c. In addition there are other oils of lower specific gravity and viscosity sold under the names of "neutral oil," "cleaning oil," "batching oil," &c. The oils in this category vary so widely that it would be difficult to specify their characteristics in any useful manner in this work. The flash-point is in all cases far above the legal limit.

SOLID PRODUCTS.

These include, in addition to paraffin or paraffin wax, and paraffin scale (unrefined paraffin wax), mineral jelly, termed pharmaceutically *paraffinum molle* and *petrolatum*, which is chiefly sold under the proprietary name of "vaseline," but is also known as "cosmoline," "saxoline," "geoline," "fossiline," "petrolina," &c. Ozokerite is not a manufactured product of petroleum, but is a natural mineral wax found in Galicia. The purified material closely resembles beeswax and is employed as a substitute for the latter. Ozokerite also yields by distillation a candle-making material similar to paraffin, but of higher melting-point. It is scarcely necessary to say that the flash-points of these products are very far above the legal standard.

SHALE OIL PRODUCTS.

SHALE SPIRIT. Gasoline of specific gravity ·640 to ·660, and naphthas of specific gravities ·718 to ·720, ·735 to ·740 and ·750 are manufactured at some works. The flash-points of the various descriptions of shale spirit are below the legal standard.

SHALE OIL. . The oils for use in lamps, sold under the names of "paraffin oil," "burning oil," "crystal oil," "petroline," &c., usually have a specific gravity of about ·810, and a flash-point of 105° F. (Abel) and upwards. A special oil for use in lighthouses is also manufactured with a specific gravity of ·814 and a flash-point of 145° F. (Abel). Another product, of still higher specific gravity (about ·836) and flash-point, is termed "marine oil." The specific gravity of intermediate oil or gas-oil produced from shale ranges from ·840 to ·865 and the flash-point from 150° F. (Abel) upwards.

LUBRICATING OIL, &C. Lubricating oils of various specific gravities and viscosities, as well as soft and hard paraffin, are among the products obtained.

COAL-TAR PRODUCTS.

NAPHTHA. It is only necessary in this statement to mention the various naphtha-products.* These include benzene (benzol), the hydrocarbon C_6H_6, which has a specific gravity of ·884, a boiling-point of 177° F., and a flash-point below the temperature of 32° F. at which it solidifies; toluene (C_7H_8), specific gravity ·871, boiling-point 232° F., flash-point about 45° F.; solvent naphtha (often described as having a specific gravity not above ·875 and as distilling between 248° and 320° F.), specific gravity often about ·867, and flash-point about 66° F.; heavy solvent naphtha or burning naphtha (sometimes described as having a specific gravity of ·880 to ·887), specific gravity often as high

* The so-called "sharp oil," used in lamps of the "lucigen" type, has a specific gravity of about 1·060, and a flash-point of about 160° F.

as ·905, and flash-point about 116° F.*; 90 per cent. benzol (of which 90 per cent. by volume distils below 212° F.), specific gravity—English ·880 to ·882, Scotch about ·870, flash-point below 15° F.; 50 per cent. benzol (of which 50 per cent. distils below 212° F.), specific gravity—English ·878 to ·880, Scotch ·867 to ·872, flash-point below 15° F.

Note.—"Benzine Collas" is a name under which a description of mineral spirit, doubtless obtained originally from coal-tar, has been sold for detergent purposes for many years. (The label used includes the copy of a testimonial from the Master of the Royal Apartments, dated Buckingham Palace, October 30, 1858.)

In order to show the relative extent to which various descriptions of petroleum products occur in commerce in this country, statistics of imports are given in Appendix I.

Various uses of petroleum products increasing.

The employment of petroleum products as liquid fuel, as a substitute for coal in the manufacture of gas for illuminating and heating purposes, as a source of power in internal-combustion engines, and as lubricants, is rapidly increasing as the attendant advantages become recognised, and adequate supplies are rendered available. An impetus has also recently been given to the use of kerosene as an illuminating agent, for it has been demonstrated that when burned in a specially constructed mantle-lamp in the form of vapour, under pressure, a brilliant light, well adapted for streets and large buildings, can be obtained from this oil at a less cost than by the use of any other illuminating agent, and as each lamp is self-contained the installation of the system can be effected without any opening of the ground such as is necessary in laying a service of gas-mains. There is, therefore, reason to anticipate further vigorous growth of this already highly important industry.

* Two descriptions of solvent naphtha are specially prepared which have flash-points a little above 73° and 100° F. respectively. These products have specific gravities ranging from ·890 to ·915, according to the character of the tar from which they are manufactured.

CHAPTER V.

"FLASH-POINT" AND "FIRE-TEST."

Explanation of flash-point.

THE Petroleum Acts are made to apply to such petroleum as, when tested in the manner prescribed, "gives off an inflammable vapour" at a temperature of less than 73° F. This wording is unfortunate, inasmuch as it has given rise to a great deal of misconception as to the real meaning of the term "flash-point," and as to its relation to the safety of an oil in storage and use.

In the succeeding chapter, the various methods of testing petroleum for the determination of its flash-point are described in detail. It is, therefore, only necessary here to enunciate the broad principle on which all such tests are carried out. A sample of the oil to be tested is placed in a vessel, and is gradually heated up until, on application of a light, a blue flame or flash is seen in the space above the surface of the liquid. The temperature of the oil at this point is noted, and this temperature is now commonly called the "flash-point" of the oil. The Act of 1879 and all previous ones, however, call this the temperature at which the petroleum "gives off inflammable vapour." This has led many persons to suppose that at this temperature the oil undergoes some physical change, and suddenly commences to evolve vapour. As a matter of fact, like all other liquids, petroleum gives off vapour at all temperatures, and would continue to do so even if cooled down to zero Fahrenheit. What the Act really means is the temperature at which the

oil gives off, or has given off, sufficient vapour to form an inflammable mixture with the air, and this is a matter entirely dependent on the conditions under which the test is carried out. By varying these conditions very wide differences may be made in the flash-point obtained with one and the same sample of oil. Consequently, to speak of the flash-point without naming the method by which it is to be determined is as meaningless as to name a degree of temperature without stating whether the Fahrenheit or Centigrade thermometer scale is intended. This fact appears to have been unknown to the framers of the Petroleum Act, 1862, in which a flash-point is specified, but no method of determining it is prescribed.

In the subsequent Acts of 1868 and 1871 a test apparatus is laid down, but it was not until 1879 that the Legislature adopted a method, known as the Abel test,* in which the conditions are so far under control that anything like uniformity can be obtained in the hands of different experimenters. Further experience has, however, shown that still greater uniformity can be obtained by improvements in this instrument and in the method of its employment.

Proportion of vapour necessary to form explosive mixture with the air.

The minimum proportion of vapour to air necessary to produce an inflammable mixture is about 1·8 per cent. An increase to 2 per cent. of vapour renders the mixture explosive, while when the proportion exceeds about 4 per cent., the liability to explosion begins to disappear, but the mixture continues to be inflammable.

Now, not only does the temperature at which an oil gives off sufficient vapour to produce such proportions depend on many conditions, but the percentages themselves are also liable to variations. It will be sufficient to discuss only the more important causes which are

* See Appendix II.

known to produce such variations, but there are doubtless many other conditions which have a more or less direct influence both on the temperature and the percentage of vapour. One of the most important conditions affecting the temperature at which an inflammable mixture of vapour and air may be produced, is the time during which the oil has been submitted to that temperature. As has already been pointed out, no ordinary sample of petroleum is homogeneous, and it is the vapour of its lighter and more volatile constituents which is first given off. If the proportion of light constituents is small, their vapour will be given off slowly, and it may take a very long time before a sufficient amount has been evolved to render a given volume of air inflammable. Consequently, in a closed vessel, if sufficient time is allowed, the vapour may continue to accumulate until an explosive atmosphere is formed, even though the oil may never have reached a temperature as high as that of its flash-point determined by a test where the time is limited. On the other hand, if the oil is contained in a vessel which is not completely closed, the effect of time may be just the reverse of that described. Thus, if the test is carried out in an open or partially open vessel, and if the rate of heating is made very slow, much of the vapour given off in the earlier stages of heating will diffuse into the outer air. In this way the proportion of lighter spirit will be diminished, and the flash-point determined by such a test will be higher than if the rate of heating had been more rapid.

Conditions affecting flash-point.

It is hardly necessary to state that the flash-point is very largely affected by the amount of ventilation which is afforded to the sample in the testing apparatus. The very wide difference between the results obtained with the test prescribed in the Act of 1871 and those of the Abel test, are principally due to the fact that in

the former apparatus the vapour at first given off escapes by diffusion, and is moreover liable to be carried away by currents of air; therefore it is not until the temperature and consequent rate of evolution of vapour are raised sufficiently to counteract this effect that a flash is obtained.

The size of the oil vessel also affects the result. Mr. Steuart stated before the Select Committee of 1896, that by increasing the diameter of the oil vessel in the testing apparatus to 9 inches, he obtained with the same sample of oil a flash-point lower by 2° F. than that given by the Abel test.

The pressure of the atmosphere is another important factor affecting the results. Careful experiments have shown that the flash-point is lowered by 1·6° F. for every inch reduction in barometric pressure. A table of corrections for height of barometer will be found in Appendix VIII., but it must be remembered that the use of this table for correcting the results of official tests has not yet received the sanction of Parliament.

It is true that in this country, where no places of importance are at any considerable elevation above the sea, the variation of barometric pressure does not usually exceed 2 or 3 inches; but it is conceivable that even in the United Kingdom, circumstances may arise in actual practice which will cause a considerable reduction in atmospheric pressure. For instance, if oil were drawn from a large tank which is hermetically closed, a partial vacuum would be formed above the surface of the liquid; and in such a case an explosive mixture of air and vapour may be formed even when the oil is at a temperature far below its legal flash-point.

The amount of vapour produced may also be increased by agitation of the oil. Mr. Beilby has shown that by the violent shaking up of samples of oil with air in a

closed vessel, an inflammable atmosphere was formed when the oil was at a temperature 5° or 6° F. below its flash-point (Abel).

If portions of the containing vessel are at a higher temperature than the oil itself, this may have a considerable effect on the rate of evolution of vapour. The liquid will creep over the surface of the heated parts by capillary attraction, and will then give off vapour at a greater rate than the bulk of the oil. The vapour so given off will no doubt have some tendency to condense on the cooler surface of the oil; but owing to the nature of petroleum vapour, such condensation will take place only to a very limited extent. The effect may be therefore to produce a larger amount of vapour than might be expected from the temperature of the oil. Thus in a badly-designed testing apparatus, if parts of the oil cup are brought to a higher temperature than the oil itself, low flash-points may be obtained; but such an apparatus would not be likely to yield uniform results. This condition has a more important bearing in the case of lamps, where the metal-work of the burner in contact with the oily wick may be at a very high temperature. Again, in a tank exposed to the direct rays of the sun the sides may be raised to a high temperature, whilst the bulk of the oil remains comparatively cool.

It is not improbable that electrification of the oil, such as may occur from friction in pipes or even in a lamp burning in the neighbourhood of electrified bodies in a dry room, may have a considerable influence on the amount of vapour emitted.

Conditions affecting inflammability of vapour mixtures.

The above are some of the conditions affecting the production of vapour; but the question whether the amount of vapour produced is sufficient to form an inflammable or explosive atmosphere depends on yet other conditions. The most important of these is the

nature of the means of ignition. This affects the results given by any particular form of testing apparatus, and it is necessary therefore to specify the means of ignition somewhat minutely in order to obtain uniform results. In general it may be said that the larger and hotter the flame, the smaller will be the proportion of vapour necessary to produce an inflammable or explosive mixture. This proportion will also depend to a less extent on the volume of the mixture which is present.

In order to show that variations in one or more of the above conditions may produce results differing widely from those given by the Abel apparatus, it is only necessary to state that Professor Dewar (1896 : Q. 7057) produced an explosion of vapour with an oil having a flash-point of 106° F. (Abel), when the temperature of the sample was only 86° F. Again, an accident occurred on May 31, 1895, at Harburg near Hamburg, where a tank containing oil of a flash-point of 107° F. (Abel) was struck by lightning and exploded, notwithstanding the fact that the temperature of the air, and presumably that of the oil, was only 82° F. at the time (1896 : Q. 1894).

Conclusions.

From the above considerations it will be seen that it is not safe to draw conclusions from the results given in a testing apparatus as to the liability of a particular oil to produce an explosive atmosphere under the ordinary conditions of storage and use. Nor would it be possible to devise a test which would take into account all the conditions which may arise in practice, or in other words, which would show the lowest temperature at which any particular oil will produce an inflammable atmosphere under all possible circumstances. This being the case, the questions naturally arise as to what is the use of a test at all, and on what principle should the legal flash-point be fixed. The answer to the first of these questions is that petroleum

of almost every degree of volatility, from solid paraffin to gasoline or even pentane, has its uses and is sold in this country. The lighter varieties evolve vapour so rapidly as to necessitate certain special precautions, while the petroleum oils, being less volatile, may be handled with comparative safety. Consequently it is necessary in the interests of public safety to draw a dividing line to separate these two varieties. Since the degree of danger increases uniformly with each degree as the flash-point becomes lower, there is no definite point at which the line can be drawn. Any such line must therefore necessarily be an arbitrary one, and it must not be supposed that there is a marked difference of danger between an oil flashing at a degree above the fixed standard and one which flashes slightly below.

Principles on which standard should be fixed.

Where, then, should this arbitrary line be fixed, and on what principle? If petroleum were now for the first time being introduced as a popular illuminant, and if we had no previous experience of its behaviour under various conditions, this question would be a very difficult one to answer.

According to present knowledge, it is useless to base the figure of the flash-point on the maximum temperature of the air in this climate, or of the oil in any particular lamp, because the conditions of the test are not the same as those which arise in actual practice. When petroleum was first introduced into this country this fact was not known; and Dr. Letheby, who advised the Home Office when the Bill of 1862 was being prepared, appears to have been under the impression that there is some one definite temperature at which each particular sample of oil commences to "give off inflammable vapour." He is said to have stated that, according to his observation and experiment, there was no ordinary place of storage or lamp which

could reach a temperature of 100° F., and he therefore recommended that the flash-point should be fixed at that figure. As no method of testing was prescribed, this can hardly be said to have been the fixing of a standard; but from the figure arrived at in 1862 on an erroneous assumption a standard has arisen, which has at any rate served the country's needs, and remained unchanged until the present day.

As a matter of fact, it is upon experience alone that a standard of flash-point should be judged, and no alteration should be made in such standard on merely theoretical grounds. The real question is whether oil of a given flash-point has shown itself to be so dangerous by reason of its volatility as to require the standard to be raised, and if so, whether the advantage in point of safety outweighs any disadvantage which may be involved.

As recent proposals for raising the standard have been based mainly on the occurrence of lamp accidents, the further discussion of this question has been dealt with in the chapter on Petroleum Lamps.

Another method of testing petroleum consists in determining, by means of a suitable instrument, the temperature at which the oil takes fire and continues to burn when a light is applied to the surface. This method has never been adopted in this country except in the case of lubricating oils, but is still in use in several of the States of America. The temperature so determined is called the "fire-test" of the oil. The results obtained, as in the case of the flash-point, are liable to variations according to the means employed in carrying out the test. So far no form of fire-test has been devised which gives nearly as uniform results as the Abel flash-test. For this reason it is not possible to give an accurate comparison between the two methods of testing. The difference usually lies between 37° and "Fire-test."

47° F.; that is to say, an oil which flashes at 73° F. in the Abel apparatus will take fire at from 110° to 120° F. in the Tagliabue cup, this latter being generally used in America for determining the fire-test.

Effect of local heating.

In applying the fire-test, if the oil is allowed to become heated locally by the igniting flame, it may be made to take fire at a considerably lower temperature than would otherwise be the case; and wide differences in the observed temperature of ignition of a particular oil may thus occur in hands of different experimenters.

CHAPTER VI.

TESTING.—FLASH-POINT, FIRE-TEST, ETC.

Kerosene.—The flash-point, or, in some cases, the fire-test, of kerosene forms the basis of legislation on petroleum in most civilised countries, and its accurate determination is equally important to the public and the trade. The customary limitation of specific gravity prevents the introduction of an undue proportion of the heavier hydrocarbons, which would injuriously affect the burning quality of the oil, but affords no security against the presence of very volatile hydrocarbons, which would render the oil unsafe for ordinary use.

Primitive method of testing.

In the early days of the petroleum industry it was the custom to test kerosene by pouring it upon the surface of warm water in a saucer, or by heating it in a cup placed in warm water, and bringing a lighted taper near the surface, but this primitive method was soon superseded by the use of instruments constructed for the purpose. Most of these instruments may be described as belonging either to the "open-test" class or to the "close-test" class. In the former division the vessel holding the sample of oil is uncovered, whilst in the latter it is covered during the progress of the test.

"Open-test" and "close-test."

Tagliabue's open-test instrument.

One of the earliest forms of open-test instruments is that of Tagliabue, shown in Fig. 1. It consists of a glass cup placed in a copper water-bath heated by a spirit-lamp. The cup is filled with the oil to be tested, a thermometer placed in it, and heat applied,

the temperatures being noted at which on passing a lighted splinter of wood over the surface of the oil a flash occurs, and, after further heating, the oil ignites. The former is the flash-point and the latter the fire-test.

Fig. 1.

Squire's open-test apparatus.

Squire's open-test apparatus was designed with a view to the ready adjustment of the test flame to the required height above the surface of the oil. The oil cup was heated in a water-bath as usual, but the test-flame was furnished by a wick slightly protruding from a long tube extending from the side of a cylindrical reservoir charged with spirit. The reservoir was carried by an arm, which swung on a vertical rod attached to a heavy base, separate from the water-bath, and the height of it could be adjusted by means of a screw, so that the flame could, by swinging the lamp, be caused to pass over the oil at any desired distance from the surface.

Directions for use.

The inventor's directions were: For 110° oil the cup should be filled to within one-eighth of an inch from the top, the bulb of the thermometer extended into the oil up to the first cut line, and the height of the test-flame fixed at three sixteenths of an inch above the edge of the cup, or five-sixteenths of an inch above the surface of the oil. The apparatus should stand quite level, and the test-flame should be trimmed down to about the size of a dried pea. The heat of the lamp should be so regulated as to raise the temperature of the oil 5° in the first four minutes, and afterwards 10° every three minutes until 90° is reached, at which point the lamp is withdrawn for three minutes to allow the temperature to become stationary (at 96° to 98°),

when the test-flame is swung, beginning at 2 inches from the cup and terminating at the same distance on the other side, the movement occupying about half a second. If no flash occurs, the test-flame is again swung after a lapse of ten seconds, repeating the operation every two or three degrees until the burning-point is reached. The lamp should be removed before a test is made, until the temperature becomes stationary. For 120° oil, the lamp should be allowed to remain until the thermometer indicates 100°, the tests being then applied in the manner described, only at every four or five degrees.

Arnaboldi's open-test apparatus.

An open-cup tester similar to that of Tagliabue, but of somewhat larger size, and provided with a mechanical arrangement for passing the test-flame over the oil, was introduced by Arnaboldi.

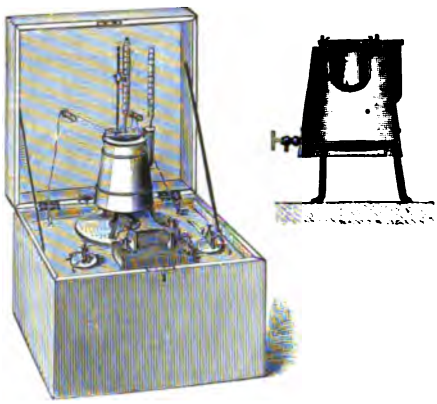


Fig. 2.

Saybolt's electric tester.

In 1879 the Saybolt electric tester (Fig. 2) was adopted by the New York Produce Exchange. In this apparatus the oil is contained in an open cup, and ignition is effected by a spark from an induction coil, passing between platinum points placed at a fixed distance above the oil. The official directions for the use of the apparatus are as follow:

Directions for use.

"Fill the metal bath with water, leaving room for displacement by the glass cup. Heat the water until the bath thermometer indicates 100° F., at which point remove the lamp. Fill the glass cup with oil to top line, indicated by the rim surrounding cup, which is

one-eighth of an inch below top edge of the cup. See that there is no oil on the outside of the cup, nor upon the upper level edge, using paper to clean cup in preference to cotton or woollen material. See that the surface of the oil is free from air bubbles before first flash is produced. Lift the cup steadily with left hand and place in the bath. Suspend the thermometer with the bulb of same immersed just from view under the surface of oil. Adjust the flashing bar and immerse the battery zincs in fluid. Try for first flash every degree until the same is obtained. Attain flash by producing spark with one stroke of the key. The stroke on the key should be such as in telegraphy is used to produce what is called a dot, that is, a short, quick stroke. The first flash produced from 110° test oil is generally obtained when the temperature of the oil has arrived at 90°. The temperature of the bath at 100° (as per note above) will carry the oil to about 90°, or, in other words, to about the first flashing point, without the aid of a lamp. When the thermometer in the oil indicates 90°, introduce lamp under the bath, and do not remove until the operation is finished. The temperature of oil when placed in bath should not be lower than 55°, nor higher than 70° F. The flashing bar must be free from oil before adjusting for test. Draughts of air must be excluded from the apartment wherein tests are made. Oil of 110° and upwards shall (after first flash) be flashed at 95, 100, 104, 108, 110, 112, 115. Oil of 120° and upwards, after first flash, 100, 105, 110, 115, 118, 120, 122, 125. Oil of 130° and upwards, every 5° after first flash, until burning-point."

1868 English open-test apparatus.

The first apparatus employed in this country in connection with the legal definition of petroleum was that described in the schedule of the Petroleum Act, 1868. It consists of a slightly conical oil-cup of thin sheet-iron,

two inches deep and two inches wide at the opening, provided with a flat rim, and a raised edge a quarter of an inch high.* Across the cup and fixed to or resting on the edge is a wire, which is thus a quarter of an inch above the flat rim. The oil-cup is supported by the rim in a tin water-bath, four and a half inches deep and four and a half inches in diameter. The outer vessel having been filled with "cold or nearly cold water," as much of the oil to be tested is poured into the cup as will fill it without flowing over the flat rim, and a thermometer with a round bulb, about half an inch in diameter, and so graduated that every 10° F. occupies not less than half an inch on the scale, is then suspended in the oil so that the bulb is immersed about an inch and a half beneath the surface. A screen of pasteboard or wood of specified dimensions† having been placed round the apparatus, a "small" flame is applied to the bottom of the water bath, and when the temperature of the oil has reached 90° F., a "very small" flame is passed across the surface of the oil on a level with the wire, this application of the test-flame being repeated for every rise of "two or three" degrees in temperature, until a "pale-blue flicker or flash" is produced. The temperature at which this occurs having been noted, the experiment is repeated with a fresh sample of the oil, withdrawing the source of heat when the temperature approaches that noted in the first experiment, and applying the test-flame at

Apparatus of "the three chemists."

Directions for use.

* It was originally intended by the three chemists, Sir Frederick Abel (then Mr. Abel), Professor Attfield, and Dr. Letheby, who had reported on the subject, that an oil-cup three inches in depth and an inch and a half in diameter, to be only about half-filled with the oil, should be employed, without any screen, but these conditions were modified, as explained in chap. vii.

† The schedule provides that the screen is to surround the apparatus about two-thirds, and is to reach "several inches above the level of the vessels."

Relation of results to fire-test.

every rise of two degrees. In the use of this apparatus, it was found that oils of 120° F. fire-test, as determined in the United States before shipment, usually had a flash-point several degrees above the legal limit of 100° F.

Insufficiency of directions for use.

It was soon discovered that the directions for testing given in the English Petroleum Act of 1868 were not sufficiently precise, and that the words "small flame" and "very small flame" were differently interpreted by various operators. As the result dealers were frequently proceeded against, and sometimes convicted, for selling kerosene flashing below the legal limit, although the oil had been passed by independent experts.

Defective nature of test.

Moreover, it was found that the open-cup tests were very untrustworthy, especially when made by comparatively unskilled and inexperienced persons.

Keates' close-test.

The substitution of a closed or covered oil-cup (Fig. 3) for the open cup was accordingly proposed by Mr. Keates, consulting chemist of the Metropolitan Board of Works. In 1871 a bill to legalise this change and to otherwise amend the existing law was introduced, but it was opposed by the petroleum trade on the ground that the flash-point of 85° F. advocated by Mr. Keates was much higher than the equivalent of the standard of 100° F. in use with the open cup.

Fig. 3.

Abel's investigation.

In 1875 the Government, with the concurrence of the Metropolitan Board of Works and of the Petroleum Association, requested Sir Frederick Abel to experimentally investigate the matter with a view to placing it on a satisfactory basis. The questions referred were as follow:

Terms of reference.

"1. Whether the method of testing petroleum as prescribed in schedule 1 of the Petroleum Act, 1871 (34 & 35 Vict., c. 105), is such as uniformly to ensure reliable and satisfactory results.

"2. If not, what alterations in the method of testing petroleum should be adopted to secure such results, due regard being had to the fact that the testing must, in many instances, be carried out by persons who have had comparatively little experience in conducting delicate experiments.

"3. Assuming it to be, in your opinion, desirable to obtain a 'flashing-test' for petroleum, whether the present 'flashing-point' of 100° F. (or its equivalent under any modified method of testing which you may propose) is, in your judgment, calculated to afford adequate protection to the public, without unduly interfering with or restricting the trade; if not, what alteration in this respect should be made."

Results of inquiry.

After a prolonged and exhaustive experimental inquiry, in which Dr. Kellner rendered valuable assistance, Sir Frederick Abel presented to the Secretary of State an elaborate report, dated August 12, 1876, wherein the questions enumerated were thus answered:

"1. The method of testing petroleum as prescribed in schedule 1 of the Petroleum Act, 1871 (34 & 35 Vict., c. 105), is not of a nature 'uniformly to ensure reliable and satisfactory results.'

"2. A method of testing petroleum has been elaborated for adoption in place of that prescribed by the Petroleum Act, 1871, due regard having been had to the fact 'that the testing must, in many instances, be carried out by persons who have had comparatively little experience in conducting delicate experiments.' This method, while resembling in its general nature the one hitherto used, is free from the defects inherent in the latter, and is so arranged that it can be carried out, with the certainty of furnishing uniform and precise results, by persons possessing no special knowledge or skill in manipulation. With ordinary attention in the first instance to simple instructions, different operators cannot fail to obtain concordant results with it, and it is so nearly automatic in its nature that it is not, like the present method of testing, susceptible of

manipulation so as to furnish different results at the will of the operator.

"3. There are not, in my judgment, any well-established grounds for considering that the present flashing-point of 100° F. is not 'calculated to afford adequate protection to the public.'

"4. With the employment of the new test, a minimum flashing-point should therefore be adopted, which is equivalent, or as nearly as possible so, to the flashing-point of 100° F., as furnished by the present test."

Determination of equivalent flash-point.

In the determination of the equivalent flash-point it was obviously necessary to deal with the conflicting views already referred to as to the proper mode of conducting the test with the open-cup instrument. One of the authors assisted Sir Frederick Abel in the conduct of this portion of the inquiry; but before the test-standard was even provisionally fixed, Mr. T. W. Keates, as representing the Metropolitan Board of Works, and Mr. John Calderwood, on behalf of the Scottish Mineral Oil Association, were also consulted. Eventually, as the result of the joint experiments, it was ascertained that the difference between the flash-points obtained with the open-cup instrument and those furnished by the Abel apparatus usually ranged from 25° to 29° F.

Mean difference 27° F.

Adopting the mean difference of 27°, the new standard was accordingly fixed at 73° F.

Application of tests to 1000 samples.

One of the authors then applied the two tests to 1000 samples of American kerosene, the first 968 samples consisting of the ordinary oil of commerce, and the remaining 32 of "water-white" oil. The following were the results obtained:

Results.

92	samples	showed	a difference	between	the two	tests of	25°.
208	,,	,,	,,	,,	,,	,,	26°.
225	,,	,,	,,	,,	,,	,,	27°.
281	,,	,,	,,	,,	,,	,,	28°.
162	,,	,,	,,	,,	,,	,,	29°.
968							

On the other hand, the majority of the last 32 samples gave smaller differences as follow:

9	samples showed a difference between the two tests of	20°.
1	sample ,, ,, ,, ,, ,,	21°.
9	samples ,, ,, ,, ,, ,,	22°.
1	sample ,, ,, ,, ,, ,,	23°.
4	samples ,, ,, ,, ,, ,,	24°.
8	,, ,, ,, ,, ,, ,,	25°.
32		

These, however, all consisted, not of ordinary petroleum oil, but of the special kind which is known in the trade under the name of "water-white" oil; therefore the exceptional results afforded by them do not affect the question, and are of interest only as showing that samples may be selected or specially prepared having flash-points by the two systems more closely approximating than those of the ordinary petroleum oil of commerce. This water-white oil, as is well understood, possesses the distinctive feature of low specific gravity in addition to that of high flash-point, being in fact produced at a considerably enhanced cost by rejecting, in the process of distilling the crude oil, an unusually large proportion of the heavier as well as of the lighter hydrocarbons, and doubtless this accounts for the smaller difference between the two tests.

Introduction of Abel test.

Before the new test was legalised, one of the authors proceeded (in 1877) to New York for the purpose of submitting the instrument to the inspectors appointed by the New York Produce Exchange, and arranging for its use in testing kerosene intended for shipment to this country.

Legalisation of Abel test.

The Abel test, as it is now commonly termed, was legalised by the Petroleum Act, 1879. The construction and use of the apparatus are fully described in Appendices II. and VII. By an oversight the length

Length of pendulum.

of the lead-line or pendulum was omitted from the schedule of the Act. This should be 24 inches from the point of suspension to the centre of gravity of the weight. The following explanatory note on the use of the pendulum appeared in the Petroleum Bill, 1883 :

Use of pendulum.

"*Note.*—For example: The pendulum having been moved from the perpendicular to position *a* (Fig. 4),

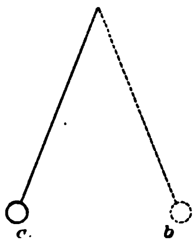


Fig. 4.

The first oscillation is from			*a* to *b*.
„ second	„	„	*b* to *a*.
„ third	„	„	*a* to *b*.
„ fourth	„	„	*b* to *a*.

The opening of the slide commences the moment the pendulum leaves position *a* in the first oscillation, and is steadily continued while it performs the first, second and third oscillations ; so that the slide is fully open when, in the third oscillation, the pendulum has reached position *b*. The slide is kept open for an instant and then quickly shut, the moment of its being quite closed again being coincident with the return of the pendulum to position *a* at the end of the fourth oscillation."

Use of clock or "metronome."

Those who have occasion to make a large number of tests will find it convenient to use a clock with a pendulum of the requisite length or a synchronised "metronome" such as is used in teaching music.

The action of the Abel test.

In the use of the Abel test it should be recognised that at each application of the test-flame a sample, so to say, of the atmosphere of the upper part of the oil-cup is withdrawn by the action of the current of air produced. This current passes downwards through the two smaller openings in the cover of the cup and upwards through the central orifice, under the influence of the heat of the test-flame, sweeping out a portion of the vapour which has been given off. It will, therefore,

often be found that an oil the flash-point of which is, say, 75° F. will flash on the first application of the test-flame if such application be made only two or three degrees below the true flash-point instead of at about 66° F. As, however, the result thus obtained depends to a considerable extent upon the temperature of the cup itself and of the mercury in the bulb of the thermometer, it would be very difficult, if not practically impossible, to obtain uniformity in tests made on this principle, and the fact that some portion of the vapour given off by the sample is eliminated before the flash-point is reached is of no consequence, as the test is otherwise an arbitrary one. With some oils of a flash-point barely 73° F. it is desirable, in order to ensure obtaining a result which subsequent tests would confirm, to begin the application of the test-flame two or three degrees below 66° F. (a safe rule being to commence 8 or even 10 degrees below the flash-point); but obviously if a given sample has a flash-point below 73° F. when tested in the manner prescribed by law, the oil represented by this sample must be regarded as petroleum to which the Acts apply even though the flash-point may not be below 73° when the testing is commenced at a lower temperature than "about 66° F."

Importance of beginning the test at a sufficiently low temperature.

In 1881, Engler and Haas made a number of experiments with the Abel and other instruments, and came to the conclusion that the provision of a stirrer in the oil-cup was desirable. Victor Meyer had previously expressed the same opinion. In the Abel apparatus a stratum of vapour is formed upon the surface of the oil, and the temperature of the oil is not uniform throughout. It is, therefore, necessary that the dimensions of the air-space above the oil, the depth to which the test-flame is inserted, the size of the orifices in the cover, the position of the thermometer-bulb, and

Use of a stirrer in the oil-cup.

other particulars should be defined with greater accuracy than would probably be necessary if a stirrer were added; but experience has shown that the Abel instrument can be readily standardised, and any number of instruments can thus be constructed to give concordant results if used with a reasonable amount of care. The addition of a stirrer, both for the vapour and for the oil, is no doubt desirable when the Abel instrument in its original or modified form is applied to the testing of oils of high flash-point, such as lubricating oils, but Dr. Engler and Dr. Bunte have expressed to one of the authors their concurrence in his view that it is not requisite when the instrument is employed in testing kerosene.

Suggestions as to the use of the Abel test.

If a number of tests are to be made with a single instrument, it will be found desirable, especially in warm weather, to cool the oil-cup and thermometer-bulb after each test, by plunging them into cold water and afterwards wiping them dry. It is perhaps scarcely necessary to say that a confirmatory test, such as it is often desirable to make, must of course be carried out with a fresh portion of the oil.

Necessary precautions.

It may not be altogether superfluous to point out that the mercurial column in the oil-cup thermometer should be carefully examined from time to time in order to ascertain that it is unbroken. Cases have occurred in which, owing to the accidental detachment of a small portion of the mercury, a flash-point far below the true one has been recorded. The oil-cup may with advantage be placed for filling upon a sheet of plate-glass, resting upon a tripod levelling stand, previously adjusted with the aid of a spirit-level. This stand should be in a good light, as the accurate filling of the cup to the point of the gauge is important. The oil should be poured in without splashing, and any bubbles which may be formed should be dispersed with a pointed strip of paper.

As the testing should be conducted in a subdued light, the reading of the thermometer will be found to be greatly facilitated by placing behind the apparatus at the requisite height a burning night-light or candle so that the light illuminates the translucent ivory scale of the thermometer. To shut off the light which would otherwise pass to the eyes of the observer a piece of paper, three or four inches square, having two slits made in it should be slipped over the thermometer-stem, the portion overlying the ivory being sufficiently cut away.

The observer should take care that when he reads the thermometer the line of vision is at a right angle with the scale.

Testing india-rubber solution.

The Petroleum Act, 1879, gives no specific directions applicable to the testing of india-rubber solution, and to meet this deficiency the first schedule of the Inflammable Liquids Bill, 1891, contained the following addition to the instructions for the use of the test-apparatus:

"If the flashing test has to be applied to substances of a viscous or semi-solid nature which cannot be poured (such as solutions of india-rubber in mineral naphtha), the mode of proceeding is as follows: About a tablespoonful of the substance to be tested is placed in the cup, and the cover is put on. The air-chamber in the water-bath is filled with water to a depth of 1½ inch, and the temperature of the water-bath is raised to 76° (for which purpose the scale of the thermometer to be used in the water-bath should range from 60° to 180°).

"The cup is then put into the bath and the temperature of the water-bath maintained at 76° throughout the test. After the lapse of fifteen minutes the test-flame is to be applied. If no flash occurs, the heating is continued for another fifteen minutes and the test-

flame again applied, and so on until a flash takes place or the temperature in the cup has reached 75°; [if a flash occurs at or]* below 72° the substance under examination has an observed flashing-point of less than 73°. The temperature at which a flash occurs is the observed flashing-point of the substance, and, subject to correction for atmospheric pressure as herein-before described, is the true flashing-point."

Testing paints.

Although some paints containing petroleum, such as anti-fouling and anti-corrosive compositions applied to ships' bottoms, are neither viscous nor semi-solid and can be poured, their flash-points cannot be satisfactorily determined in the manner prescribed for the testing of petroleum owing to their being insufficiently fluid to admit of the formation of convection currents. In other words, the heat applied by means of the water-bath and air-jacket does not circulate freely through the contents of the oil-cup, with the result that the part of the liquid undergoing the test which is in contact with the walls of the cup acquires a much higher temperature than is indicated by the thermometer, and a flash-point may be thus recorded which is far below the true flash-point. For the efficient testing of such liquids a stirrer in the oil-cup is needed.

Results affected by atmospheric pressure.

After the Abel instrument had been in use for some time, the discovery was made that the results which it furnished differed materially according to the barometric pressure at the time of testing. This source of variation appears to have been first observed accidentally in Germany; and as the result of a series of experiments made in an air-tight chamber in the Jewish Hospital in Berlin, it was ascertained that the difference in the flash-point amounted to about 0·30° C. for each 10 millimetres difference in the height of the barometric column.

* The words in square brackets have, apparently, been inadvertently omitted.

A table of corrections was accordingly prepared in Germany for use with the Abel Pensky tester. This table is given on p. 100.

Experiments at different altitudes.

To obtain further evidence as to the effect of alteration in barometric pressure on the flash-point, a series of experiments was conducted by one of the authors in association with Sir Frederick Abel at different altitudes in Switzerland, and results exhibiting a difference of about 2° F. in the flash-point for 1 inch difference in barometric pressure were obtained.

Results obtained.

The experiments were, however, not carried out with a view of determining the exact extent of variation, the number of tests made being insufficient to form the basis of a table of corrections. The results actually obtained are given in the following table :

No. of Sample.	London. Bar. at 30″.	Paris. Bar. at 30·15″.	Bouveret. Bar. at 28·75″.	Visp. Bar. at 27·5″.	Chamounix. Bar. at 26·425″.	Zermatt. Bar. at 24·3″	Riffel. Bar. at 21·5″
1	71° F.	71° F.	68° F.	66° F.	63° F.	60° F.	55° F.
2	73	73	70	68	64	62	56
3	76	76	73	71	68	65	63
4	78	78	75	73	70	67	64
5	85	85	83	80	78	75	70
Difference in barometer from London observation . . .			1·25″	2·5″	3·575″	5·7″	8·5″
Mean difference in flash-point per inch of mercurial column . . .			2·05°	2°	2·2 38°	1·93°	1·76°

Effect of a tropical climate.

It was also found that the effect of a tropical climate upon the liberation of vapour from the oil resulted in the flash-point being considerably lowered; and as the Indian Government, in adopting the Abel test,

had copied the directions verbatim from the English Act, the result was that several cargoes of oil, which were certified as of proper flash-point at the time of shipment, were refused admittance at the port of Calcutta.

Experiments in India and England.

In order to investigate the matter one of the authors proceeded to India, and from a series of experiments, made there and afterwards in England in conjunction with Sir Frederick Abel and with the assistance of Dr. Kellner, it was demonstrated that a much lower flash-point than that furnished in a temperate climate was liable to be obtained when the Abel test was employed in a tropical climate in the manner prescribed in the English Act. Further experiments made by Dr. Warden, analyst to the Government of Bengal, Professor Pedler, of Calcutta, Dr. Lyon, Sir Frederick Abel, Dr. Kellner, and one of the authors showed that the depression in the flash-point was largely due to disengagement of vapour in the act of filling the oil-cup. Although prolonged cooling of the oil minimised the liability to such disengagement of vapour, it was found that the only practical means of eliminating this source of error was to get rid of the vapour before commencing the test or before the flash-point was reached.

Results.

Modification adopted.

The vapour was readily removed by gently blowing over the surface of the oil before placing the cover on the cup, or by the use of an aspirator attached to the cover, or by leaving the test-slide withdrawn for some time; but the method finally adopted consisted in commencing the test many degrees below the flash-point, so that the vapour is withdrawn by the current of air created by the test-flame in successive quantities too small to cause a flash before active volatilisation of the oil begins. Thus modified, the test gives results at a tropical temperature which agree very closely with

those which it furnishes in a temperate climate. The slight loss of volatile constituents which occurs when the test is so performed is of no practical importance, since such loss takes place even by exposure to the air in hot climates. (See a joint communication from Sir F. Abel and one of the authors in the *Chemical News*, May 2, 1884.)

Directions for use of Abel test in tropical climates.

In October 1887 Sir Frederick Abel drew up directions for the use of the Abel instrument in tropical climates. These directions will be found in Appendix III.

Testing Burma crude petroleum.

Since the Abel test was legalised in India, it has been found necessary to determine the flash-point of Burma crude petroleum, which is solid at common temperatures. In testing this oil in the Abel instrument, rapid evolution of vapour commences while the bulk of the oil in the cup remains solid, and the thermometer therefore does not indicate the temperature of the oil in contact with the walls of the cup from which vapour is being evolved. To meet this difficulty, one of the authors suggested the addition of a delicate thermometer, which is fixed in the cover of the oil-cup in a vertical position, so that the small cylindrical bulb is just immersed in the oil, and is distant only a tenth of an inch from the side of the cup.

Investigation of petroleum-testing in Germany.

In 1880 the subject of petroleum-testing was investigated in Germany on behalf of the Government, and the Abel instrument was selected as the best, but, as exception was taken to the personal error liable to be introduced by the method of applying the test-flame, the modification devised by Pensky, of Berlin, was adopted. The improvement consists in effecting the movement of the slide and application of the test-flame by a clockwork arrangement, which ensures uniformity.*

Abel-Pensky test adopted.

* This instrument is here very fully described, as advantage will probably be taken of the first opportunity to legalise its use in this country.

Description of the instrument. A section of the instrument—which in all other respects is practically identical with the ordinary Abel apparatus—and the details of the clockwork mechanism, are shown in Figs. 5 and 6, which also give the dimensions in millimetres.

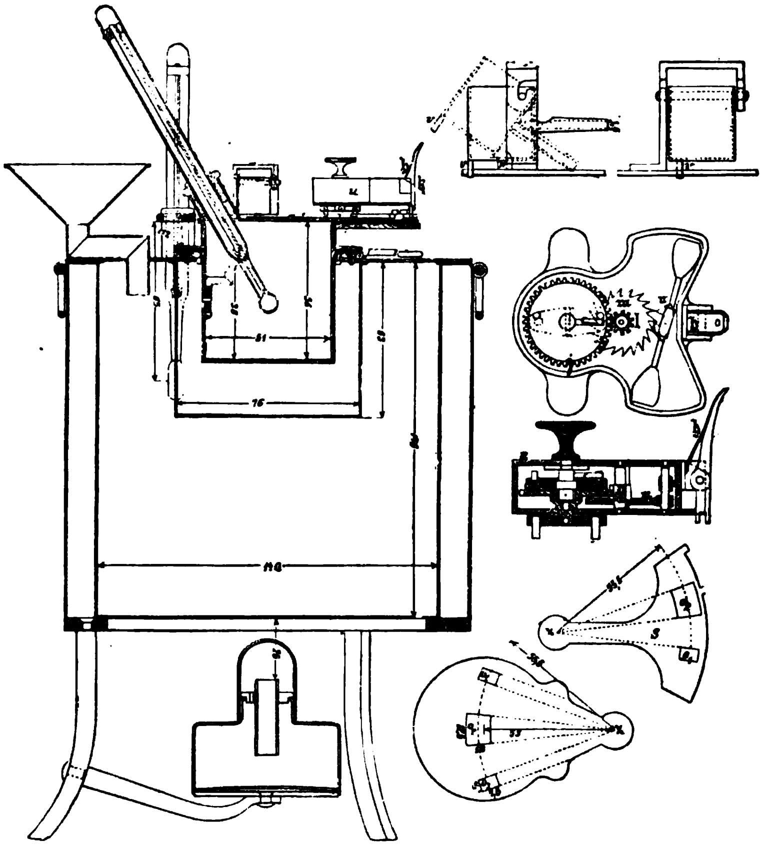


Fig. 5.

The slide *S* pivoted on the centre *z* is set in motion by the arm *d* moving on a central axis. This arm carries on its under side two pins e_1, e_2. When the slide is in its normal position—*i.e.*, closing the openings o_1, o_2, o_3—one of the pins e_1 rests against the steel plate *f* on the right-hand side of the slide, and the other e_2 is held by the catch *g*. On the axis of the

arm *d* is fastened the spring-case *u* containing a spiral spring.

To wind up the clockwork, the knob *b* is turned half round, further winding being prevented by a stop. To

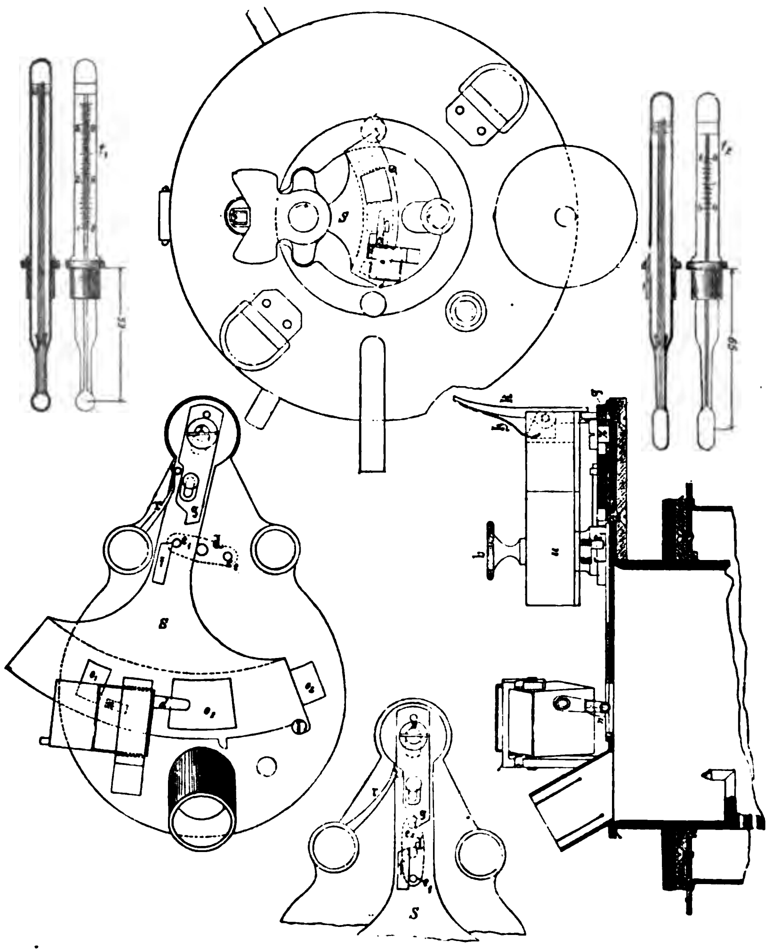


Fig. 6.

move the slide, the trigger *k* is pushed towards the spring *h*, the catch *g* being thus drawn back and the pin e_2 released. The spiral spring unwinds and presses the other pin e_1 against the slide *S*, moving this slide aside to the left and uncovering the apertures. As

soon as the pin e_1 is carried by the revolution of the arm *d* past the steel plate *f*, the slide is forced back to its former position by the spring *r*, and the pin e_1 is stopped by the catch *g*, which returns it to its original place as the trigger *k* is released. These movements are repeated every time the test is applied. The uncoiling of the spiral spring and movement of the slide are regulated by the escapement *m n p*. The three holes in the lid of the oil-cup and the two holes in the slide (the lateral movement of the slide uncovering and covering the third hole in the lid) are of the same area as those in the Abel instrument, but not quite the same shape, on account of the circular motion of the slide. The lamp is tipped by a nose-piece *n*, and on its return to the perpendicular is prevented from swinging backwards by a stop *v*.

The Abel-Pensky apparatus, as used in Germany, furnishes results about 3° F. higher than those given by the Abel instrument, but the clockwork modification employed in India is standardised to afford flash-points corresponding with those obtained with the original Abel instrument.

Directions for use.

The following is the method of applying the Abel-Pensky test prescribed in Germany:—

The testing should be carried out in an apartment of medium temperature and free from draughts. The petroleum samples should be in closed vessels, and have been long enough in the room to have acquired the same temperature, otherwise the tests will not be satisfactory.

The height of the barometer must be observed before commencing operations, and the temperature at which the test is to be first applied varies with the pressure indicated, according to the following table:—

Height of Barometer.	First Test applied at
685 to 695 millimetres	+14° C.
695 to 705 ,,	+14°
705 to 715 ,,	+14·5°
715 to 725 ,,	+15°
725 to 735 ,,	+15·5°
735 to 745 ,,	+16°
745 to 755 ,,	+16·5°
755 to 765 ,,	+17°
765 to 775 ,,	+17°
775 to 785 ,,	+17 5°

If the barometer varies from the normal pressure of 760 mm. by more than 2½ mm. either way, the actual flash-point observed is corrected in accordance with the table on p. 100. The table being arranged for intervals of 5 mm., intermediate pressures are counted as 0 or 5, according to the figure which they most nearly approach —viz., 742 counts as 740, 743 as 745, and so on. The instrument must be set level on the testing-table, with the aid of a spirit-level or plumb-line, before it is filled, and it should be at such a height that the red mark on the water-bath thermometer is on a level with the eye of the operator. The bath is next filled with water at +50° to 52° C. until a portion runs out through the overflow pipe, to which an indiarubber tube should be attached to convey the surplus water away without splashing the apparatus or table. If cold water is used for filling the bath, it must be warmed by the heating lamp before putting in the oil-cup, care being taken that the base ring does not get overheated. The test lamp is prepared for use by being packed with loose cotton wool, which is then saturated with petroleum, any surplus being poured out. If this is not attended to, the tipping of the lamp at the moment of applying the test might cause drops of oil to fall on to the lid of the tester and vitiate the results. The wick must also be cleansed from any adherent incrustation or char.

The oil-cup, with its cover and thermometer, are to be thoroughly clean and dry, and all traces of oil from preceding tests are to be removed by drying and absorption. Finally, the petroleum to be tested, if not at least 2° C. cooler than the lowest of the temperatures recorded in the foregoing table, must be cooled down to that point, together with the oil-cup, the latter being dipped into cold water. To obtain very exact results, it is advisable to use water cooled to + 11° C. for this purpose, and to keep the oil-cup in it long enough for proper cooling. Before inserting the oil-cup, the water-bath is heated up to 54° to 55° C., the temperature indicated by the red mark on the thermometer scale. Meanwhile, the oil is poured into the oil-cup by means of the pipette, until the extreme point of the indicator just projects above the surface of the liquid. It is important that this limit should not be exceeded, but if this should happen, the cup must be emptied, dried carefully, and refilled. Any bubbles forming on the surface of the oil must be dissipated by pricking with the warm charred point of a burnt-out match. The table on which the cup stands during the operation of filling should be perfectly horizontal and quite near to the water-bath, to minimise the risk of tilting or shaking the cup. The oil is poured into the centre of the cup and not against the sides, and to prevent bubbles the nozzle of the pipette should be kept below the surface of the liquid. The lid of the cup is put on directly after pouring in the oil, the thermometer being previously inserted in its socket and pressed down tightly, avoiding contact between the ebonite plate under the clockwork and the knobs *K* on the bath, as this would prevent the lid from fitting properly. The insertion of the oil-cup into the bath must be done without tilting or shaking, and to avoid the risk of this the cup, previously cooled by ice

and water to 8° C. (to prevent the oil getting warm while filling), may be put into position before filling. Should the water bath be at a higher temperature than 54° to 55° C., it must be cooled by the addition of cold water, and when that degree is reached the lamp is extinguished.

When the oil approaches the temperature at which the first test is to be applied, in accordance with the foregoing table, the test lamp is lighted and the flame adjusted until, when viewed from the front, it is of the same width as the white bead on the lid. This is important, as the size of the flame has an influence on the flashing temperature. The clockwork is then wound up by turning the milled head as far as it will go in the direction indicated by the arrow. On releasing the catch by pressing on the trigger, the slide slowly and regularly moves aside, and at the end of two seconds has returned to its original position. During the movement of the slide the behaviour of the test-flame as it approaches the surface of the oil must be carefully observed, particular attention being directed to sheltering the apparatus from all draughts and from the breath of the operator. This is facilitated by the provision of a glass plate fixed to the draw-out side of the case containing the apparatus. The test is to be repeated at every $\frac{1}{2}$° rise of the thermometer until a flash is obtained. Before the absolute flash-point is reached the size of the test-flame will be observed to increase by a kind of halo when dipped towards the oil, but the true flash is a bluish, lightning-like flame extending over the whole free surface of the oil. The temperature indicated by the thermometer is subject to correction, both as regards barometric pressure and error, if any, of the thermometer itself, according to the variation ascertained on standardising the instrument. The test is repeated with a fresh portion of the same oil, after

cooling the oil-cup and lid, drying and freeing them, as well as the thermometer, from all adherent drops of oil, and reheating the bath to 55° C.

TABLE FOR CORRECTION OF APPARENT FLASH-POINTS TO THE NORMAL BAROMETRIC PRESSURE OF 760 MILLIMETRES.

Millimetre-Pressure.																				
685	690	695	700	705	710	715	720	725	730	735	740	745	750	755	**760**	765	770	775	780	785
Flash-Points, Centigrade Scale.																				
16·4	16·6	16·7	16·9	17·1	17·3	17·4	17·6	17·8	18·0	18·1	18·3	18·5	18·7	18·8	**19·0**	19·2	19·4	19·5	19·7	19·9
16·9	17·1	17·2	17·4	17·6	17·8	17·9	18·1	18·3	18·5	18·6	18·8	19·0	19·2	19·3	**19·5**	19·7	19·9	20·0	20·2	20·4
17·4	17·6	17·7	17·9	18·1	18·3	18·4	18·6	18·8	19·0	19·1	19·3	19·5	19·7	19·8	**20·0**	20·2	20·4	20·5	20·7	20·9
17·9	18·1	18·2	18·4	18·6	18·8	18·9	19·1	19·3	19·5	19·6	19·8	20·0	20·2	20·3	**20·5**	20·7	20·9	21·0	21·2	21·4
18·4	18·6	18·7	18·9	19·1	19·3	19·4	19·6	19·8	20·0	20·1	20·3	20·5	20·7	20·8	**21·0**	21·2	21·4	21·5	21·7	21·9
18·9	19·1	19·2	19·4	19·6	19·8	19·9	20·1	20·3	20·5	20·6	20·8	21·0	21·2	21·3	**21·5**	21·7	21·9	22·0	22·2	22·4
19·4	19·6	19·7	19·9	20·1	20·3	20·4	20·6	20·8	21·0	21·1	21·3	21·5	21·7	21·8	**22·0**	22·2	22·4	22·5	22·7	22·9
19·9	20·1	20·2	20·4	20·6	20·8	20·9	21·1	21·3	21·5	21·6	21·8	22·0	22·2	22·3	**22·5**	22·7	22·9	23·0	23·2	23·4
20·4	20·6	20·7	20·9	21·1	21·3	21·4	21·6	21·8	22·0	22·1	22·3	22·5	22·7	22·8	**23·0**	23·2	23·4	23·5	23·7	23·9
20·9	21·1	21·2	21·4	21·6	21·8	21·9	22·1	22·3	22·5	22·6	22·8	23·0	23·2	23·3	**23·5**	23·7	23·9	24·0	24·2	24·4
21·4	21·6	21·7	21·9	22·1	22·3	22·4	22·6	22·8	23·0	23·1	23·3	23·5	23·7	23·8	**24·0**	24·2	24·4	24·5	24·7	24·9
21·9	22·1	22·2	22·4	22·6	22·8	22·9	23·1	23·3	23·5	23·6	23·8	24·0	24·2	24·3	**24·5**	24·7	24·9	25·0	25·2	25·4
22·4	22·6	22·7	22·9	23·1	23·3	23·4	23·6	23·8	24·0	24·1	24·3	24·5	24·7	24·8	**25·0**	25·2	25·4	25·5	25·7	25·9

If the result of the second test agrees with the first within $\frac{1}{2}$°, the average is taken as the apparent flash-point. If, however, the difference is 1° or more, a third test is necessary; and, provided the results of the three do not differ more than $1\frac{1}{2}$°, the average is taken. In case of a greater divergence a fresh set of tests must be made. In the case of oils flashing at the first application of the test-flame, the actual flash-point may be higher than is indicated by the thermometer, the accumulation of vapour in the oil-cup causing the flash to occur sooner than it would in ordinary circumstances. If it is desired to accurately test such oils, the operation is begun at a lower temperature than usual, and repeated at lower degrees until no flash is produced on first opening the slide.

The apparent flash-points must be corrected for pressure, according to the table on p. 100, by finding the observed flash-point in the column headed by the existing height of the barometer, and proceeding in the same row to the column headed 760, which will show the actual flash-point at normal pressure. Fractions between the figures given in the table are to be counted as the figure to which they most nearly approach. Any error recorded by the standardiser of the apparatus must be corrected before applying the correction in the table.

Standardising the instruments.

By an order of the Imperial Chancellor, dated July 21, 1882, the Kaiserliche Normal-Aichungs-Kommission was empowered to standardise and stamp instruments for testing petroleum, particular attention being devoted to the following points:

(*a*) The dimensions of the apparatus.

(*b*) The accurate timing of the slide movement.

(*c*) The accuracy of the thermometer.

(*d*) The correctness of the flash-points indicated by the apparatus.

(*e*) The accuracy of the metallic barometer supplied with the instrument.

The examination of the thermometers should not take place until they have been delivered.

In verifying the dimensions of the apparatus, the following variations from the exact standard are allowed in :

	Millimetres.
The thickness of the metal plates	0·2
The diameter of the lamp spout	0·2
The distance of the point of the filling indicator from the upper edge of the cup	0·5
The distance from the lower corner of the inside of the lamp spout to the upper face of the cup-lid when the lamp is fully tipped	0·5
The thickness of the ebonite ring	0·5
The inside diameter and height of the oil-cup; the width of the brass ring; its distance from the upper edge of the cup; the distance of the axis of the slide from the centre of the cup-lid and the centre of the three apertures; the diameter of the bead; and the dimensions of the tube for the insertion of the thermometer t_1	1·0
The distance of the centre of the bulb of the thermometer t_1 from the end of the sheathing-tube and from the underside of the cup-lid	1·0
The dimensions of the water-bath, and of the outer cylinder; the width of the ebonite ring on the bath; and the distance of the lowest mark on the scale of either thermometer from the enlargement on the tube	2·0

The variation of time allowed for the slide movement is 0·2 second over or under the prescribed standard. The thermometer t_1 may not vary from the normal instrument more than 0·2° C. when tested in four places on the scale, and the thermometer t_2 not more than 0·5° C. when tested in two places. Furthermore, successive portions of the same sample of oil consecutively examined should not show a greater divergence

of flash-point than 0·75° C., and the average of five or seven such tests should not differ from the average of the same recorded by the standard by more than 0·5° C., an oil approximating to the standard flash-point being used for the experiment. The metallic barometer belonging to the apparatus should not differ more than 2 millimetres from the standard at the ordinary room temperature. It must be examined with a view to ascertaining the influence of sudden alterations of pressure or continued shaking of the instrument on its accuracy between the limits of 680 and 790 mm. The instruments which satisfy the tests imposed are stamped by the Normal-Aichungs-Kommission on all the removable portions, and the amount of variation or error of flash-point to be allowed for is indicated. The maker's name, the number of the instrument, and the year of examination are included in the stamping, and all the particulars are inscribed on a certificate issued by the standardiser together with the following measurements:

(*a*) Distance of the point of the filling indicator from the upper edge of the oil-cup.

(*b*) Distance of the lowest inside point of the lamp spout from the under surface of the cup-lid when the lamp is fully tilted.

(*c*) Distance of the central point of the oil-thermometer bulb from the under surface of the cup-lid.

To guard against any alteration of these points subsequent to standardising, the Aichungs-Kommission send out with each apparatus examined a stamped gauge, consisting of a rectangular steel plate on one side of which is a projection for controlling the measurement *a*; on another a second projection bounded by two flutings to measure *b*, and furnished with a projecting stud on one of its flat surfaces for gauging *c*. To examine *a*, the gauge is applied to the edge of the

oil-cup, so that the projection hangs down inside and the mark on it is touched by the point of the filling mark. For the second verification, *b*, the clockwork is set in motion, and the apertures in the lid are wedged open so that the mouth of the lamp is at its lowest point. The gauge is then applied under the lid, and the lower inside corner of the spout should coincide with the end of the smaller projection. For examining *c*, the side of the gauge opposite to the smaller projection used for *b* is applied to the under side of the lid, when the stud should exactly touch the middle of the bulb

Fig. 7.

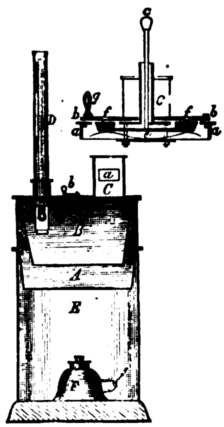


Fig. 8.

of the thermometer. The length of the lamp spout can also be verified, a mark cut at right angles to the plain side of the gauge showing the exact size. The edge of the spout-mouth should coincide with the mark; and should either the top or bottom corner fail to do so, the apparatus is out of adjustment.

Tagliabue's "pyrometer."

As early as 1862, Tagliabue patented in America a "coal-oil pyrometer," for use either as a closed cup to determine the flash-point, or as an open cup for ascertaining the igniting point of the oil. The apparatus is shown in Figs. 7 and 8, the upper portion of Fig. 8 showing the cover of the instrument illustrated in

Fig. 7, while the larger illustration in Fig. 8 shows a simpler form of the apparatus. The cylindrical water-bath is supported by a metal stand having an aperture near the bottom for the introduction of a small spirit lamp. The vapour disengaged from the oil by the application of heat mixes with atmospheric air admitted through perforations in the lid, and an inflammable mixture is thus formed, which ascends into the dome. The flash-point of the oil is ascertained by the insertion of a lighted taper or match into an opening in the dome, at intervals, until a slight explosion occurs. To determine the igniting point of the oil, the cup is opened by partially revolving the cover, and the test-flame is held for one or two seconds in contact with the escaping vapour.

Directions for Use.—Remove the cover *a* of the instrument by turning it until the vertical slots come into position to allow of its being taken off, take out the oil-cup, fill the outer vessel with water to a distance of within 2 inches from the top, replace the oil-cup and fill it with the oil to be tested to within $\frac{3}{8}$ inch from the top, replace and secure the cover in position, supply the lamp with alcohol and trim the wick to give a small flame, light it and place it under the water-bath. The mercury in the thermometer will soon begin to rise; watch this carefully until it approaches to within about 20° F. of the temperature at which the oil is expected to flash, remove the lamp, press down the brass knob *c*,* which will open the valves and allow air to enter into the instrument and vapour to rise in the dome *C*. Into the aperture of this insert a very small lighted taper, and if the vapourising point has been

* This knob is connected with a bar *e*, the ends of which normally cover apertures *f* in a pivoted plate *b*. The plate may be moved by means of a handle *g* when it is desired to open the cup. The bar *e* is supported by a spring.

reached, a slight "puff" will occur; if this should not take place, replace the lamp and allow the mercury in the thermometer to ascend very slowly, 2° or 3° F. per minute; remove the lamp and perform the same operation with the lighted taper until the slight "puff" is produced; proceed very slowly with this operation, and when the "puff" occurs take a simultaneous reading of the thermometer; this indicates the flash-point. To ascertain the burning-point of the oil, replace the lighted lamp and allow the thermometer to rise about 8° F.; now remove the lamp, swing back the cover by means of the handle *g*, and pass the lighted taper quickly across the oil without inclining the taper downwards; if the burning-point has been attained, the oil will ignite; if not, cover the oil and replace the lamp, watching the thermometer carefully, and not allowing the mercury to rise more than 3° or 5° F. between the tests. When the oil takes fire, read the thermometer, and this will give the igniting-point. It is advisable in all cases to make more than one test of the oil; in each new test the water and oil should be changed, and the instrument allowed to cool. Having learned the vapourising point in the first operation, in the succeeding ones the instrument can be more carefully watched, and probably the flash-point recorded will be lower than in the first operation. When "high grade" oils are being tested, sand is placed in the outer vessel instead of water. One of the authors has not found it possible to obtain concordant results with this instrument. In some cases the results closely agree with those furnished by the Abel apparatus, but in most instances they appear to be from 6° to 8° F. higher, and occasionally 10° or 12° higher. This apparatus was formerly used in Germany. The simpler form of the instrument shown in Fig. 8 consists of a water-bath *A*, an oil-cup *B*, the hood *C*, with an

opening *a*, into which the test-flame is inserted; the body *E*, the thermometer *D*, the lamp *F*, and the pivoted cover *b* over the air-inlet.

Wisconsin tester. The instrument officially employed in the State of Wisconsin has a copper oil-cup with a copper cover in which there is a small opening for the insertion of the test-flame. In 1882 the State Board of Health of New York adopted a form of the tester last described, embodying improvements suggested by Professor Arthur H. Elliott, the chief of which was the substitution of a glass for a metal cover. The following is the official description of the apparatus and of the mode of applying the test:

Elliott tester.

Description. The instrument consists of a sheet-copper stand $8\frac{1}{2}$ inches high, exclusive of the base, and $4\frac{1}{2}$ inches in diameter. On one side is an aperture, $3\frac{1}{2}$ inches high, for introducing a small spirit lamp about 3 inches in height, or better, a small gas-burner in place of the lamp when a supply of gas is at hand. The water-bath is also of copper, and is $4\frac{1}{8}$ inches in height and 4 inches inside diameter. The opening in the top is $2\frac{7}{8}$ inches in diameter. It is also provided with a $\frac{1}{4}$-inch flange which supports the bath in the cylindrical stand. The capacity of the bath is about 20 fluid ounces, this quantity being indicated by a mark on the inside. The lower portion of the copper oil holder is $3\frac{3}{8}$ inches high and $2\frac{3}{4}$ inches inside diameter. The upper part is 1 inch high and $3\frac{3}{8}$ inches diameter, and serves as a vapour-chamber. The upper rim is provided with a small flange which serves to hold the glass cover in place. The oil holder contains about 10 fluid ounces when filled to within $\frac{1}{8}$ of an inch of the flange which joins the oil-cup and the vapour-chamber. In order to prevent reflection from the otherwise bright surface of the metal, the oil-cup is blackened on the inside by forming sulphide of copper by means of sulphide

of ammonium. The cover is of glass, and is $3\frac{3}{8}$ inches in diameter. On one side is a circular opening closed by a cork through which the thermometer passes. In front of this is a second opening $\frac{3}{4}$ of an inch deep and the same in width on the rim, through which the flashing-jet is passed in testing. The substitution of a glass for a metal cover more readily enables the operator to note the exact point at which the flash occurs. A small gas jet, $\frac{1}{4}$ inch in length, furnishes the best means for igniting the vapour. Where gas cannot be had, the flame from a small waxed twine answers very well. The test shall be applied according to the following directions:

Directions for use.

Remove the oil-cup and fill the water-bath with cold water up to the mark on the inside. Replace the oil-cup and pour in enough oil to fill it to within $\frac{1}{8}$ of an inch of the flange joining the cup and the vapour-chamber above. Care must be taken that the oil does not flow over the flange. Remove all air bubbles with a piece of dry paper. Place the glass cover on the oil-cup, and so adjust the thermometer that its bulb shall be just covered by the oil. If an alcohol lamp is employed for heating the water-bath, the wick should be carefully trimmed and adjusted to a small flame. A small Bunsen burner may be used in place of the lamp. The rate of heating should be about 2° F. per minute, and should in no case exceed 3°. As a flash torch, a small gas jet $\frac{1}{4}$ inch in length should be employed. When gas is not at hand employ a piece of waxed linen twine. The flame in this case, however, should be small. When the temperature of the oil has reached 85° F., the testing should commence. To this end, insert the torch into the opening in the cover, passing it in at such an angle as to well clear the cover, and to a distance about half-way between the oil and the cover. The motion should be steady

and uniform, rapid and without any pause. This should be repeated at every 2° F. rise of the thermometer until the temperature has reached 95° F., when the lamp should be removed and the test should be made at each degree of temperature until 100° F. is reached. After this the lamp may be replaced if necessary, and the test applied at each 2° F. The appearance of a slight bluish flame shows that the flash-point has been reached. In every case note the temperature of the oil before introducing the torch. The flame of the torch must not come in contact with the oil. The water-bath should be filled with cold water for each separate test, and the oil from a previous test carefully wiped from the oil-cup. The instrument to be used in ascertaining the igniting-point of oils shall consist of the cylinder, the copper oil-cup, together with a copper collar for suspending the cup in the cylinder, and an adjustable support for holding the thermometer. The test for ascertaining the igniting point shall be conducted as follows: Fill the cup with the oil to be tested to within $\frac{3}{8}$ of an inch of the flange joining the cup and the vapour-chamber above. Care must be taken that the oil does not flow over the flange. Place the cup in the cylinder and adjust the thermometer so that its bulb shall be just covered by the oil. Place the lamp or gas-burner under the oil-cup. The rate of heating should not exceed 10° F. a minute below 250° F., nor exceed 5° a minute above this point. The testing-flame described in the directions for ascertaining the flash-point should be used. It should be applied to the surface of the oil at every 5° rise in the thermometer till the oil ignites.

Objection to the test.

An inconveniently large quantity of oil is required for this test, and the results obtained, while not differing greatly from those furnished by the Abel instrument, are less concordant.

Granier tester. The first "automatic" tester introduced was that of Granier, which has been officially employed in France, and is thus described: The apparatus consists of a small copper cup divided into two concentric parts, the walls of the inner division being conical. In the aperture at the apex of the cone is inserted a tubular wick on a small mandrel which stands in a depression formed in the bottom of the cup, so as to be perfectly upright. There is a small tube in the outer division to serve as a gauge for the quantity of oil, and as an overflow pipe to carry away any slight excess. Heat is applied to the oil, not by a lamp below, but by means of a bent copper wire fixed in the aperture of the lid, so as to receive heat from the test-flame and convey it to the oil, into which its two ends dip. The cover has a circular opening over the test-flame, with a small lid also pierced by a central aperture.

Directions for use. The method of applying the test is as follows: The apparatus must be clean, and the wick must be renewed if carbonised to a depth exceeding 1 mm. The wick, fixed upon its metallic mandrel, is placed in the metallic cone in the cup, so as to rest evenly on the bottom of the cup. The oil to be tested, the temperature of which should not exceed 25° C., is poured into the cup in such a manner that it runs into the wick, the cup being filled to the top of the connecting tube. The cover is then placed on the cup, the small lid in the centre of the cover closed, and the thermometer placed in its socket. To ascertain the degree of inflammability, a lighted match is held near the small orifice in the centre of the small lid, and kept there for several seconds, and the temperature at which a petroleum vapour flame appears and remains above the orifice is carefully noted. If a persistent vapour flame is not obtained, the wick should be lighted at several points, so as to produce combustion all round the edge, and

the small lid closed. The rise in temperature is to be carefully observed, the degree at which a slight explosion occurs and extinguishes the flame being the degree of inflammability. Should this be either 32°, 33°, or 34° C., the operation is to be twice repeated with fresh portions of the sample, and the average of the three taken as the correct result. Liquids passing the test of 35° C. are considered as of the second class, and those failing to do so are held to belong to the first class, of inflammable liquids.

Unsatisfactory character of the test.

One of the authors has made a considerable number of tests with the Granier apparatus, but has found the action so unsatisfactory that he is unable to state how the results compare with those given by the Abel instrument.

Parrish's naphthometer.

In Parrish's naphthometer, an "automatic" tester which has been largely used in Holland, the cover of the oil-cup is provided with a wick holder, fixed centrally in a short tube of greater diameter, and carrying a lamp wick which passes down into the oil. The oil thermometer is inserted in a tube which is attached to the cover of the cup. This tube communicates (1) with the external air through orifices in the cup at the upper end, (2) with the air in the upper part of the oil-cup through a lateral aperture, and (3) with the oil in the cup through openings in the bottom of the tube. A screen prevents the heat of the test-flame from affecting the thermometer. The oil-cup fits in a water-bath which is placed in an outer casing containing the spirit lamp for heating the apparatus. In applying the test, cold water is poured into the water-bath, and the oil-cup is filled to within 1 centimetre from the top. The flame of the spirit lamp is regulated to a length of 1 to $1\frac{1}{2}$ centimetre, and the testing-flame should not exceed 6 or 7 millimetres in length. The heat from the latter causes a current of air to pass down the tube containing

the thermometer, over the surface of the oil, where it mingles with the oil vapour, and to issue near the test flame, ignition occurring when the flash-point of the oil is reached.

Foster's tester.

The Foster automatic tester (Fig. 9), employed in Ohio, is similar in principle to Parrish's tester. In the figure the oil-cup is shown at *A*, the water-bath at *B*, the body of the apparatus, forming an air jacket, at *C*, and the flash-jet at *D*.

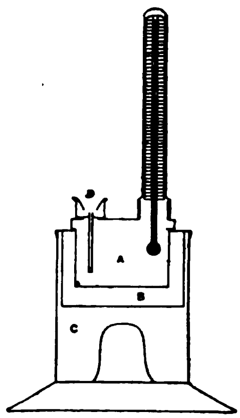


Fig. 9.

The instrument consists of a copper lamp-furnace containing a water-bath and oil-cup, the latter surmounted by a closed vapour-chamber, which is pierced at two points symmetrically placed for the reception of a thermometer and a flashing-lamp or taper. The apparatus is elliptical in shape, the thermometer being placed in one focus of the ellipse, and the flashing-taper in the other. The flashing-taper consists of a small cylindrical wick-holder, which is supported by radial arms attached to a ring, and rests upon a similar ring at the bottom of an open, shallow basin, the spaces between the radial arms giving egress to the oil vapour, while the wick itself extends down into the body of the oil within the cup. An inverted conical thimble, resting upon the rim of the basin, prevents the dissipation of the vapour. The thermometer is mounted in a copper tube cut away in front to expose the scale, the bulb of the thermometer, when in position, being within the body of the oil at a definite distance below the surface. A space round the tube of the thermometer, of definite diameter and distance above the surface of the oil, allows of the passage of a downward current of atmospheric air when the flashing-taper is alight. An

index is placed within the water-bath and within the oil-cup for maintaining uniformity in the filling of each. The heating lamp of the lamp-furnace has its wick adjustable to regulate the rate of heating.

Directions for Use.—(1) Remove the thermometer, with its mounting, from the oil.

(2) Lift off the oil-cup containing the flashing-taper, and half fill the open water-bath with water.

(3) Now take out the wick-holder from the oil-cup, and fill this vessel with the oil to be tested, pouring in the oil at the place of the wick-holder, and noting the gauge-mark at the thermometer hole; pour in the oil very gradually as the surface approaches the gauge-mark. The gauge-mark consists of a small pendant shelf, and the oil-cup is properly filled when the upper surface of the oil just adheres to the lower surface of the gauge-mark. Too much care cannot be taken at this point; therefore, having ceased pouring, tip the cup so that the oil flows away from the gauge, and then gradually restoring it to the horizontal, see that the surface again adheres, and add a little more oil if it does not.

(4) See that the wick of the flashing-taper be adjusted to give a very small flame—a flame that does not exceed one quarter of an inch in height. A flame that exhibits as much blue at its base as yellow at its top is right.

(5) Now replace the oil-cup in the water-bath; return the flashing-taper to its place, inverting the conical thimble round it, and return the thermometer to its place upon the cup; in doing this be sure that the casing of the latter is pushed down upon the cup as far as it will go.

(6) Half fill the lamp beneath with alcohol, light it and put it in its place beneath the water-bath. Now note the rate of increase in temperature as shown by

the thermometer, and adjust the wick to raise the temperature at the rate of 2° F. per minute. When the temperature has reached 100° F., light the flashing-taper and observe it closely. As soon as the oil under test has reached its "flashing point" the flame of this taper will be extinguished by the "flash," and the temperature is to be noted at the instant the flame of the taper is extinguished.

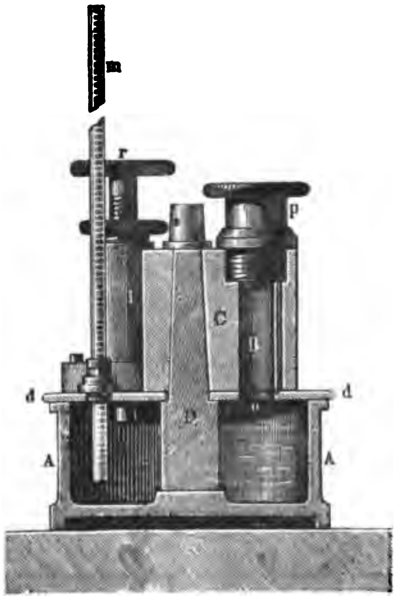


Fig. 10.

Relation of results to those of Abel tester.

Although the Foster tester belongs to the closed vessel class, one of the authors finds that it gives results from 14° to 20° F. higher than those furnished by the Abel instrument, the extent of the difference depending upon the character of the oil.

Salleron-Urbain tester.

In the Salleron-Urbain tester, which has been used in France in the examination of petroleum, the flash-point is deduced from the pressure exerted by the vapour evolved at a given temperature. It consists, as shown in Fig. 10, of a copper or brass vessel *A*, from the bottom of which rises a conical pillar *D*. The vessel is hermetically closed by a cover *d*, which carries a guide-block *C*, fitting and pivoted on the pillar *D*, and containing a cylindrical chamber *B*, closed above by a screw stopper and indiarubber ring *p*, and communicating below with *A* by a hole in the lid. A graduated tube of glass *m*, 35 cm. long, and divided into millimetres; a thermometer, and a regulator, consisting of a stuffing-

box l, containing a piston raised or lowered by a screw r, to adjust the pressure of water in the tube m, are all fastened hermetically to the lid.

Directions for Use.—To test an oil, water is poured into the vessel A and the lid with its appendages is fastened down, the block C being so turned that the cylinder B is not in communication with A. The oil being placed in B and the stopper screwed down, the whole apparatus is placed in warm water until the thermometer indicates the required temperature. The height of the column of water in m is reduced to 0 on the scale by turning the regulator screw r, and the block C is turned round so as to allow the oil to flow from B into A. The heat in the vessel A vapourises a portion of the oil, and the pressure generated is recorded by the rise of water in the graduated tube. The inventors prepared the table on p. 116, showing the pressure produced by heating a "normal petroleum" free from all constituents of less than ·735, or more than ·820 specific gravity.

Salleron and Urbain give also the following as the determined vapour pressures (vapour tensions) of petroleum products of various densities:

Density at 15° C.	Tension in mm. of water at 15° C.	Density at 15° C.	Tension in mm. of water at 15° C
·812	0	·756	125
·797	5	·735	410
·788	15	·695	930
·772	40	·680	1,185
·762	85	·650	2,110

As regards this test, Engler and Haas state that the method rests entirely upon the belief that the vapour pressures vary directly with the flash-points of different varieties of petroleum, which is not in all cases correct, **Defective nature of test.**

as the presence of a small quantity of highly volatile hydrocarbon, presumably too small in quantity to sensibly affect the flash-point, increases the pressure in the apparatus. The conclusion is, however, expressed that oils whose vapour pressure at 15° C. is not greater

Temperature.	Pressure expressed in millimetres of water in the measuring tube.	Temperature.	Pressure expressed in millimetres of water in the measuring tube.
°C.		°C.	
0	34·5	18	73
1	36	19	76
2	37·5	20	79
3	39	21	82·5
4	41	22	86
5	43	23	90
6	45	24	95
7	47	25	100
8	49	26	105
9	51	27	110
10	53	28	116
11	55	29	122
12	57	30	129
13	59	31	136
14	61·5	32	144
15	64	33	155
16	67	34	163
17	70	35	174

than is represented by a column of 64 millimetres of water may be considered safe.

Test-tube method of testing.

When only a small quantity of oil is available for testing, the flash-point may be approximately determined by slowly heating the oil in a test-tube 4 or 5 inches in length by about three-quarters of an inch in diameter, and inserting the burning end of a piece of thin twine into the mouth of the tube at intervals

after agitating the oil. The tube should be about one-third filled with the oil, and a delicate thermometer used to take the temperature. In this way results which do not differ materially from those furnished by the Abel instrument may be obtained after a little practice.

Testing atmosphere of tanks, &c.

The subject of the detection and measurement of petroleum vapour in the atmosphere of tanks and other spaces engaged the attention of one of the authors about eight years ago. He was at one time accustomed to employ an alcohol flame in testing for petroleum vapour, but becoming impressed with the importance of being provided with a delicate and thoroughly trustworthy means of determining the proportion of inflammable vapour present, he was led to investigate the subject. After experimenting with various methods of testing, with results given in a paper published in the *Minutes of Proceedings of the Institution of Civil Engineers*,* he devised, in consultation with Professor Clowes and Mr. Robert Redwood and with the assistance of Messrs. W. J. Fraser & Co., a testing apparatus in which the hydrogen flame is employed.† It is well known that a non-luminous flame burning in a space from which light is excluded, in air containing a small proportion of inflammable gas or vapour, is seen to be surrounded by a faint halo, which is termed the "flame-cap." The advantage possessed by a hydrogen flame over other flames in point of sensitiveness when thus employed as a test for inflammable gases has long been recognised; and Mr. Pieler,‡ in 1883, after referring to the previous

Use of alcohol flame.

Experimental investigation.

"Flame-cap." Advantage of hydrogen flame.

* "Redwood on the Transport of Petroleum," *Min. of Proc. Inst. C.E.*, cxvi. (1893–94), Part II.

† English Patent No. 187, 1893.

‡ *Ueber einfache Methoden zur Untersuchung der Grubenwetter.* Aachen, 1883.

recommendation of the hydrogen flame for testing by Messrs. Mallard and Le Chatelier,* described an apparatus in which the gas generated in a Dobereiner lamp was burned in a specially constructed test-lamp, for use in testing samples of air from the workings in coal-mines. Professor Clowes is entitled to the credit of having devised a form of miners' testing-lamp, which depends for its success upon the employment of hydrogen stored under pressure. In the Redwood testing-lamp compressed hydrogen is also used.

Clowes' miners' test-lamp.

Redwood's test-lamp.

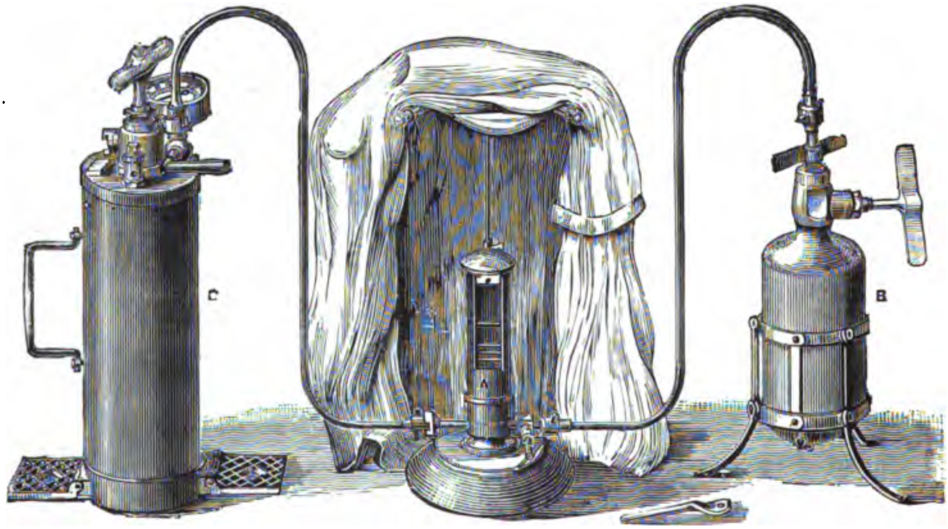


Fig. 11.

Description.

The complete appliances are shown in Figs. 11 and 12.† They consist of the lamp *A*, the reservoir of compressed hydrogen *B*, and the sampling vessel *C*, in which the sample of air for examination is collected. The lamp is shown in section in Fig. 12. *A* is the hydrogen inlet tube with the regulating valve *B*, and *C* is the hydrogen jet. *D* is the inlet tube for the

* *Ann. d. Mines*, 7th Ser., xix.

† The apparatus is supplied by the sole makers, W. J. Fraser and Co., 98 Commercial Road East, London, E.

sample of atmosphere to be tested. The bore of this tube is greatly contracted, and immediately above the point at which the tube enters the base of the lamp is an arrangement of baffles, surmounted by three discs of wire gauze of at least 28 wires per lineal inch, or not

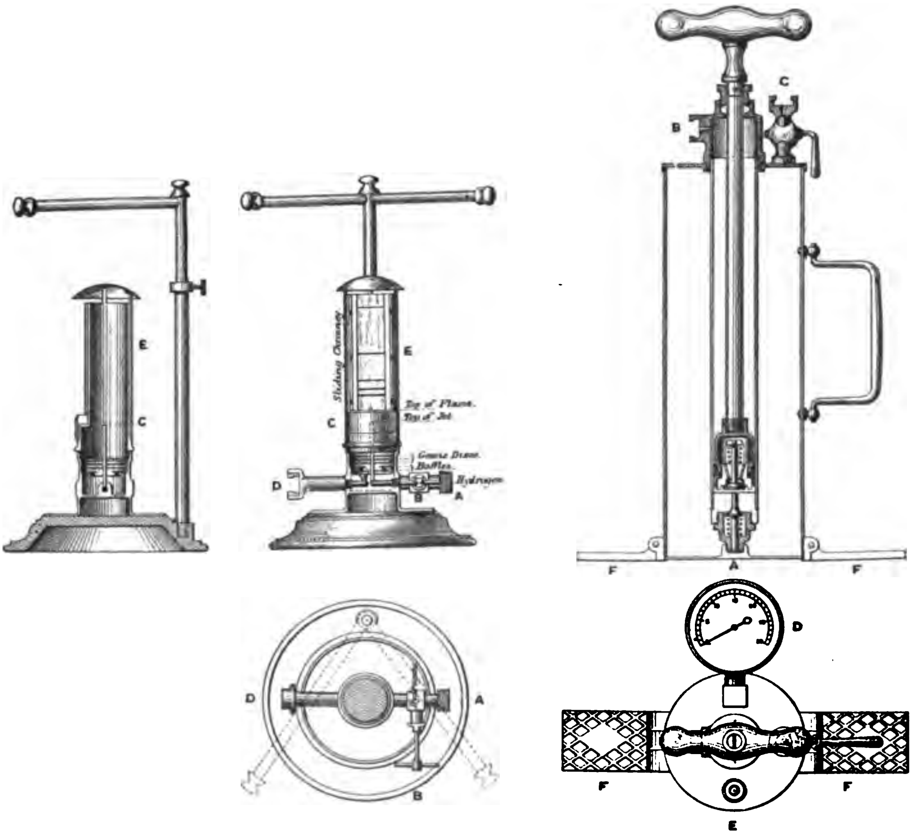


Fig. 12.

less than 784 openings per square inch, the flow of the gaseous mixture to the flame being thus regulated, and passage of flame into the collecting-vessel being prevented. The chimney *E* fits air-tight at the base, but is capable of vertical movement on an inner tube, the front of which is removed. The chimney is partly of metal and partly of glass, the metallic portion being

blackened inside, and on the glass window, lines corresponding with various heights of flame-caps may be marked. The top of the hydrogen jet-tube is 10 mm. (0·4 inch) below the bottom of the window. Attached to the base of the lamp is a telescopic support for a cloth, which envelops the head of the observer and excludes light when the testing apparatus is used in an undarkened room. The construction of the collecting-vessel is shown in section in Fig. 12. *A* is the compression-pump, which is furnished with a metallic spring-piston, fitting the pump cylinder without the use of leather or other material, and lubricated with plumbago. Surrounding the pump is an annular space, in which the sample of atmosphere is stored. *B* is a collar to which may be attached a flexible suction-tube of any desired length. *C* is a cock, to which is connected a copper tube conveying the sample to the test-lamp. The bore of this cock is very much reduced. *D* is a pressure gauge, and *E* a spring valve lifting at 30 lbs. pressure. *F F* are hinged brackets, on which the feet of the operator are placed while the pump is being worked. A handle is provided by which the cylinder can be conveniently carried. The capacity of the pump is 14·84 cubic inches, and of the annular space 169·14 cubic inches, thirty double strokes of the pump being required to charge the vessel to a pressure of 30 lbs. per square inch, when it will contain $\frac{1}{3}$ cubic foot of the atmosphere sampled. It is desirable that the collecting-vessel should be fitted with a relief valve, as the apparatus is often used in places in which the dial of the pressure gauge cannot be easily seen. The hydrogen cylinder may be of any desired size, but what is known as a 5-feet cylinder is of convenient dimensions. When charged to the usual pressure of 120 atmospheres, it holds enough gas to supply a 10-mm. flame for ten hours, and is quite portable.

The whole apparatus may be packed into two small boxes, and may thus be readily taken on board a vessel.

Mode of use.

In the use of the apparatus, the first step is to connect the hydrogen cylinder with the lamp, taking care that the unions are screwed up gas-tight. The sliding chimney of the lamp being raised about half way, the gas is then cautiously turned on at the cylinder, the regulating valve on the lamp being left open, and a light is applied to the hydrogen jet. The valve on the hydrogen cylinder is then adjusted so as to give a flame rather more than 10 millimetres (0·4 inch) in length, and the lamp chimney pushed down until there is an opening of only about a quarter of an inch in height at the bottom. This opening is left for the supply of air to the hydrogen flame during the few minutes occupied in the warming of the chimney. As soon as the moisture which at first condenses upon the cold glass has evaporated, the lamp is ready for use, and assuming the collecting-vessel to have been already charged with the sample to be tested and connected with the lamp, all that remains is for the observer to completely close the sliding chimney of the lamp, adjust the hydrogen flame by means of the regulating valve on the lamp, so that the tip of the flame is only just hidden when the eye of the observer is on a level with the bottom of the window, place his head under a cloth, such as is used by photographers, so as to exclude light,* and as soon as his eyes have become sufficiently sensitive, turn on the tap of the collecting-cylinder, and carefully observe what takes place in the lamp chimney. The tap may at once be turned on fully, as the contraction of the outlet and inlet orifices, already referred to, prevents the sudden rushing out of

* It is preferable to use the lamp in a darkened apartment, when this is possible.

the contents of the cylinder, and the sample will be gradually delivered into the test lamp during a period of more than two minutes, which is ample time for noting the effect. The rate of delivery is, of course, a gradually diminishing one, but this is not found to be attended with any inconvenience, the conditions being the same in each experiment. In this way, a proportion of vapour, considerably below that which is required even for the production of an inflammable mixture, and still lower than that which is needed to give an explosive atmosphere, may be detected by the formation of a flame-cap of greyish-blue colour, which, though faint, is nevertheless easily seen, especially after a little practice. With an increase in the quantity of vapour, the flame-cap first becomes much better defined, though it is not greatly augmented in size, and then considerable enlargement of the cap occurs, this condition being arrived at before the atmosphere becomes inflammable. One of the authors and his brother, Mr. T. Horne Redwood, have succeeded in obtaining photographs of flame-caps, which are reproduced in Plate I. The results of experiments made by one of the authors show that even the proportion of vapour which furnishes the large flame-cap *F* is considerably below that necessary for the formation of a mixture which is combustible under the conditions of the experiments, and far smaller than that which produces an explosive mixture. The test is, therefore, a delicate one, and it is obvious that if the interior of a tank or other space be freed from vapour until a sample of the atmosphere gives no flame-cap with this apparatus, an ample margin of safety will be provided, even allowing for the fact that on the large scale, under some circumstances, combustion might occur when the proportion of vapour was smaller than the minimum quantity found to be requisite in the experiments made.

Delicacy of test.

PLATE I.

To face page 122.

PETROLEUM VAPOUR FLAME-CAPS OVER THE STANDARD HYDROGEN FLAME.

A. Standard hydrogen flame in air free from vapour.
B. Flame-cap with 0·05% of pentane vapour.
C. ,, ,, 0·10% ,, ,,
D. Flame-cap with 0·3% of pentane vapour.
E. ,, ,, 0·6% ,, ,,
F. ,, ,, 0·8% ,, ,,

Density of petroleum vapour.

In taking a sample of air in a tank it must be remembered that the density of the vapour of petroleum is always much greater than that of the air. The density of the vapour varies with the chemical composition of the hydrocarbons volatilised. Thus the vapour of pentane (C_5H_{12}), a hydrocarbon of the paraffin series present in American crude petroleum, and of which gasoline is largely composed, is 2·5 times heavier than air, whilst that of heptane (C_7H_{16}) is 3·4 times heavier than air.

Collection of sample.

The collecting-vessel may be used in the tank if the proportion of vapour present is known to be small, but even in such cases it is better to employ a short suction-tube, the open end of which can be placed at the lowest point in the tank, where the heavy vapour would probably be found in largest quantity. If, on the other hand, the atmosphere of the tank is suspected to contain so much vapour that there would be danger of its producing insensibility when taken into the lungs, and especially if the compartment is entered through a small manhole, it would obviously be most improper that any one should be sent into the tank, and in that case the sample should be taken by the use of a long suction-tube reaching to the bottom.

Satisfactory results given.

The lamp and its accessories have now been in practical use for many years, and have given the most satisfactory results. In reporting upon a serious accident which occurred on board the s.s *Tancarville* through the explosion of a mixture of petroleum vapour and air, the inspectors for the Board of Trade made the following suggestions :—

"When repairs require to be carried out in a vessel which has been carrying petroleum, there should, in our judgment, be a formal handing over of the vessel to those by whom the repairs are to be undertaken, and a certificate that the tanks and all dangerous spaces have,

as far as practicable, been adequately cleansed and ventilated and rendered free from risk of explosion or fire. If from any cause a complete certificate of this sort cannot be given, then it should be clearly notified which tanks or spaces have not been cleansed and are still dangerous."

This recommendation has been generally acted upon, and such certificates are now given.

Close and open flash-points and fire-test.

Lubricating Oils.—In this country it is customary to determine the close and open flash-points and fire-test of these oils. The two latter may be ascertained by heating the oil at the rate of 10° F. per minute in a porcelain crucible about two inches in diameter, which is filled with the sample to be tested to about a quarter of an inch from the top and placed in a sand-bath, a gas-flame $\frac{3}{16}$ inch in diameter being passed across the surface, on a level with the edge of the crucible, at each rise of two degrees of temperature, indicated by a sensitive thermometer, the bulb of which is immersed in the oil, until a flash takes place, and subsequently, on further elevation of temperature, the oil ignites and continues burning. The more usual practice, however, is to test the oil in a special form of apparatus, and, having determined the close flash-point, to remove the cover of the oil-cup and proceed to ascertain the open flash-point and fire-test by using a test-flame in the manner described.

Pensky-Martens tester.

The apparatus most largely in use is that known as the Pensky-Martens tester, which is shown in Fig. 13, with the test-flame in position for igniting the vapour; the cover of the oil-cup being shown in plan and side view, and a handle, for removing the oil-cup, in the separate figures.

Description of the instrument.

The cover of the oil-cup consists of two parts—viz., the portion joined to the rim, and an upper portion which revolves through a small arc. In each portion

there are three orifices, the central one being twice the area of the two lateral ones. These orifices may be made to coincide, or the openings may be completely closed, according to the relative positions of the two portions of the cover. The lower part of the cover is fitted with a vertical rod serving as a support to a tube. This tube can be rotated upon the rod by turning the

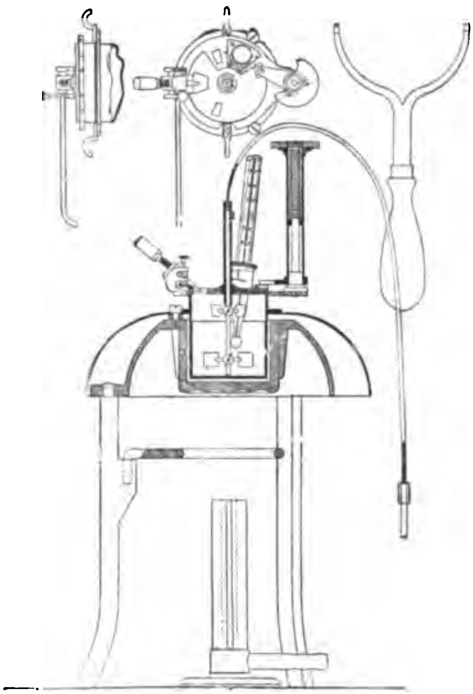


Fig. 13.

non-conducting milled head at the upper end, and the action compresses a spring. At the lower end the tube is provided with an arm which, by the action of the spring, is held against a vertical stud. A pin projecting downwards from the arm engages with a slot in the revolving portion of the cover, and on turning the milled head the openings in the upper portion of the cover are brought over those in the lower portion. At the same time, a flange projecting from the edge of the

revolving portion of the cover comes into contact with the oscillating test-jet, and this is depressed, so that at the same moment when the central openings coincide, the test-flame is brought to the orifice. On releasing the pressure requisite to turn the milled head, the openings in the cover are again closed by the action of the spring, and the test-jet is brought back to the horizontal position by the weight at the opposite end. This weight is attached to a stem forming a screw valve, by means of which the size of the test-flame can be adjusted. The gas is supplied through a lateral tube forming one of the supports on which the jet oscillates, the other support consisting of a small stud. In the lower part of the cover of the cup there is a socket for a thermometer, and in the centre of the cover there is a tube through which the stem of the stirrer passes. This stirrer is provided with a pair of arms working in the oil, and a smaller pair in the vapour-space above the oil. It is revolved by means of a flexible wire stem. The oil-cup is furnished with a pair of hooks for convenience in removing it from the bath when hot by means of the forked holder shown. The heating-vessel consists of a cast-iron air-bath with an annular chamber exposed to the flame, and a brass jacket, which serves to check radiation. The jacket is separated from the iron casting by a considerable space at the sides and by a distance of a quarter of an inch at the top. The oil-cup rests upon the jacket, and therefore does not come into contact with the cast iron. Beneath the bath there is a disc of wire gauze which is fitted to a swinging arm, so that it may be turned aside and the flame of a Bunsen burner allowed to impinge upon the bath when a high temperature is required.

Rate of heating. The flame of the burner may be regulated so that the temperature of the oil rises at the rate of about

10° F. per minute. In employing this or any other form of close-test instrument in the testing of lubricating oils, it is important that the samples should be free from water, as the presence of aqueous vapour in

Freedom of sample from water essential.

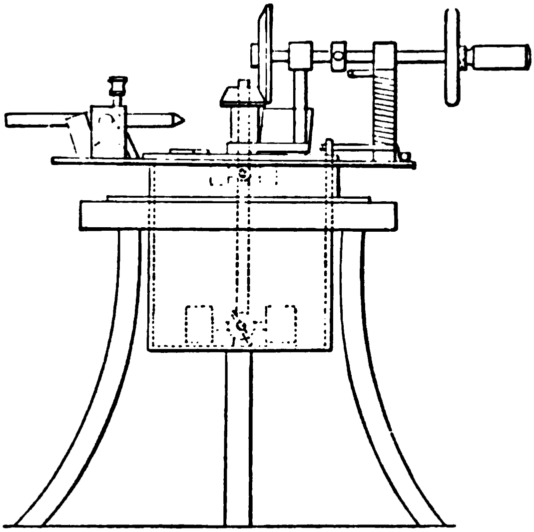


Fig. 14.

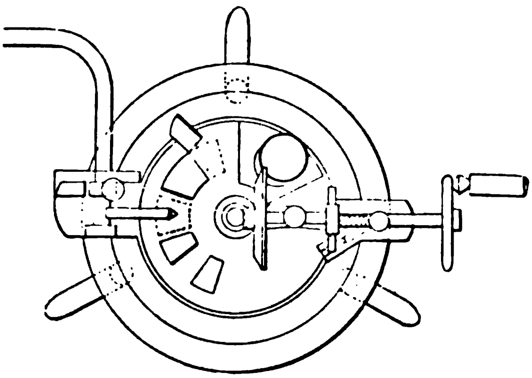


Fig. 15.

the upper part of the cup prevents the occurrence of the "flash."

Gray's tester.

Figs. 14 and 15 show Gray's instrument for determining the flash-point of heavy oils. The apparatus consists of a brass oil-cup of the same dimensions as

that employed in the Abel instrument, supported on a tripod stand and covered with a tight-fitting lid through which passes a steel shaft carrying on the end within the cup two stirrers, one for the oil and the other for the vapour. The upper end of the shaft terminates in a bevelled wheel engaging with another similar wheel on a horizontal shaft supported by two bearings and rotated by a handle fixed in an ebonite disc on its further extremity. This shaft also carries a collar from which project two pins at diametrically opposite points. These, when the shaft is drawn out a little way so as to disengage the bevel wheels, come into position for applying the test-flame. In the lid are three openings—one immediately in front of the test-flame, and the others on either side of it. The sliding cover is pierced with two orifices corresponding to those on the lid, and is kept closed (as shown in Fig. 15) by a spring while the bevel wheels are in gear. On drawing back the shaft, one of the projecting pins engages with the horizontal arm of an upright rod connected with the slide, which is turned round when the handle of the shaft is moved about a quarter of a revolution, the openings in the lid being thus uncovered and the test-flame simultaneously applied.

Substitute for gas. Where gas is not available for the test-flame, a good substitute is obtained by passing a current of air or hydrogen through cotton wool or other absorbent material saturated with gasoline.

Directions for use. The following are the directions for use prescribed by the inventor: The oil-cup being filled up to the mark inside with the oil to be tested, the thermometer is placed in its socket and heat is applied either by a direct flame or by the interposition of a sand-bath. The test-flame is adjusted to a diameter of about one-eighth of an inch. During the heating the stirrers should be rotated at short intervals, and in proportion

to the rate at which heating progresses. When the expected flash-point is approached, the heating should be more gradual, to ensure greater accuracy in the test; and a rough test to ascertain this point may be first made. Observations may be taken every degree or half-degree, giving the stirrer a few turns before each. The rate of heating is immaterial, provided it is not too rapid to allow of readings being taken.

Other Products.—The various commercial descriptions of mineral spirit obtained from petroleum and shale oil have flash-points very far below the limit fixed by law, but it is nevertheless sometimes necessary in the administration of the Acts to make a formal application of the prescribed test. This can be done without risk, but care should be taken that the oil-cup is not filled or emptied in proximity to a flame.

Testing mineral spirit.

Burning oils of very high test, and gas-oils of this description, are usually tested in the Pensky-Martens instrument.

Testing gas-oils, &c.

SPECIFIC GRAVITY.

The specific gravity will be seen from the particulars given in chap. iv. to afford a good indication of the character of the product. It may be determined with sufficient precision for this purpose by the use of an accurate hydrometer with an "open" scale, but the temperature must also be taken, and if this exceeds or falls short of 60° F. the necessary correction must be made. The correction depends to some extent upon the character of the product. In the case of kerosene it is usual for commercial purposes to add to, or deduct from, the observed specific gravity ·004 for every 10° F. above or below 60° F.; thus ·796 at 70° F., or ·804 at 50° F., would be ·800. The co efficient of expansion of mineral spirit is higher, and of lubricating oils lower,

Hydrometer. Correction for temperature.

than that of kerosene, so that for these products the addition or subtraction should be respectively somewhat greater and somewhat smaller, ·005 and ·003 being nearer than ·004 to the actual figure.

Westphal balance. The instrument known as the Westphal Balance, which can be obtained of any philosophical instrument maker, may sometimes be conveniently used instead of the hydrometer.

BOILING-POINT.

Determination of boiling-point. The determination of the boiling-point of mineral spirit, which is a valuable means of identification, can be best carried out by the use of a globular flask, of about two fluid ounces capacity, with a tubular neck from the side of which a vapour-tube extends. The flask is half-filled with the sample, the neck is closed by a cork carrying a thermometer, the bulb of which is just above the bottom of the flask, and the vapour-tube is connected with a condenser. Heat being applied, the temperatures are noted at which active ebullition begins, and at which the distillation of the sample is practically finished.

Pressure test for petroleum spirit. In advising the railway companies on the construction of vessels suitable for the conveyance of petroleum spirit, the authors found it necessary to devise a test by means of which the relative volatility of various products may be distinguished, from the point of view of the pressure which may be developed in a closed vessel on increase of temperature. The following is a description of the instrument which, after numerous experiments, was adopted for the purpose :*

A thin glass tube, 6 inches long by 1 inch in diameter, is joined at its upper end to a short length of $\frac{1}{4}$-inch tubing and at its lower end to a long capillary tube

* The makers of this instrument are Messrs. Müller and Co., 148 High Holborn, W.C.

(1 mm. bore), which is bent up in the form of a U-tube and is graduated in inches.

The 1-inch tube is marked at a point near the bottom and again near the top, these two marks being in such a position that the space between them is 90 per cent. of the total space above the lower mark.

The test is to be carried out as follows:

Fit the short ¼-inch glass tube with a piece of stout rubber tubing covering the whole of the glass tube and projecting about ¾ inch above. Wire this firmly on in two or three places. Fix the apparatus upright; pour in mercury up to the lower mark on the bulb; draw a little air through the mercury into the bulb to ensure that the mercury column in the capillary tube is unbroken. Pour in the spirit to be tested until it is well up to the upper line. Place the apparatus vertically in a vessel of water cooled down to 50° F. When the spirit has attained this temperature add a little spirit, if necessary, to bring the level up to the upper mark, then fit a strong screw pinch-cock on to the rubber tubing close above the glass tube, and screw up very firmly. Remove the apparatus from the cold water, and place it in a vessel of water heated to 100° F., taking care that the level of the water is well above the top of the rubber tubing so that any leakage may be observed. Maintain the water at this temperature for half an hour, at the end of which time observe the height of the mercury column by the scale marked on the capillary tube. The height should not exceed 24 inches if the spirit is to be contained in the vessels recommended for the purpose.

OTHER TESTS.

For scientific, industrial, or commercial purposes many other tests are applied to petroleum, shale-oil, and coal-tar products. Crude petroleum is fractionally

Fractional-distillation test. distilled in the laboratory with a view to learning what results it may be expected to yield in the refinery, and it is frequently necessary also to determine the chemical composition. The results of fractional distillation form the principal basis of valuation of coal-tar products. **Colour. Burning quality.** The colour and burning quality of kerosene and other burning oils are experimentally determined. The Trinity House contract conditions for mineral oil intended for use in lighthouse lamps specify that:

Trinity House specification.

(1) The mineral oil required to be supplied under this contract is to be of the best possible quality, the greatest care is to be taken in its preparation, and it must be perfectly free from sulphuric acid.

(2) In all cases, whether the oil be petroleum or paraffin, its flashing-point is to be determined by using the apparatus described in Schedule 1 of the Petroleum Act of 1879.

(3) If the oil be petroleum, its flashing-point is to be not lower than 125° F. (close test), and it is to distil between 302° and 572° F., the temperature of the vapour, not that of the liquid, being taken.

(4) If the oil be paraffin, its specific gravity is to be not less than 0·810, nor greater than 0·820, at 60° F.; its flashing-point is to be not lower than 140° F. (close test), and it is to distil between 302° and 572° F., the temperature of the vapour, not that of the liquid, being taken.

(5) The illuminating power of the oil supplied, whether petroleum or paraffin, is to be equal to that of the best colza oil when consumed in a Trinity House Argand lamp.

For the distillation test about 250 grammes of the oil may be taken, the operation being conducted in an ordinary distillation flask, with the bulb of the thermometer midway between the shoulder of the flask and the lateral tube leading to the condenser. The upper part of the flask should be wrapped in asbestos cloth.

Viscosity test of lubricating oils. In reporting upon lubricating oils, the colour (of "pale" oils) and viscosity are also recorded. The latter quality, which is a measure of lubricating value, is expressed in terms of the time occupied by the outflow

of a given quantity at a specified temperature from the orifice of a specially constructed apparatus, Redwood's Viscometer being the standard instrument in this country. Sometimes the lubricating power is also directly determined by testing the oil on a friction-testing machine, though the results thus obtained are usually of doubtful value. The "cold-test" of such oils is also tested, this being the temperature at which the sample, when slowly cooled, deposits solid hydrocarbons or ceases to flow. Occasionally the loss sustained by the oil on exposure in a capsule to an elevated temperature; the percentage of fixed oils present, or absence of such oils; and the freedom from impurities, some of which may act injuriously upon metallic surfaces, or from substances added to give artificial viscosity; have to be ascertained. The testing of paraffin is usually confined to the determination of the "melting-point," as it is called, which is really the setting-point, and the percentage of oil, water, and dirt present. Solar-oil distillate and American gas oil are subjected to tests prescribed in the Gas Companies' contract conditions.

Redwood's standard viscometer.

Fricton test.

"Cold-test."

Loss on heating.

Composition.

Freedom from impurities.

Paraffin testing.

Gas-oil testing.

It does not fall within the scope of this work to describe these additional tests in detail; and for further particulars of them, as well as of the chemical examination of petroleum products, the reader is referred to the more comprehensive work to which allusion is made in the preface.

CHAPTER VII.

LEGISLATION RELATING TO PETROLEUM (HISTORICAL).

Act of 1862. THE history of petroleum legislation in this country dates from 1862, in which year an "Act for the safe keeping of petroleum" was passed, and came into force three months later. In the first section of this Act, petroleum is defined in rather curious wording. The definition reads as follows: "Petroleum for the purposes of this Act shall include any product thereof that gives off an inflammable vapour at a temperature of less than one hundred degrees of Fahrenheit's thermometer." It was intended to legislate only for the more volatile products, but the intention of the Act as expressed in its wording was undoubtedly to include all petroleum of whatever flash-point, and this interpretation has been upheld in a Court of Law.*

Under this Act, vessels carrying petroleum on entering a harbour were required to conform to the regulations of the harbour authorities in respect of the place of mooring.

The Act of 1862 also provided that not more than 40 gallons might be kept within 50 yards of a dwelling house or of a building in which goods were stored, except in pursuance of a licence from the local authority.

The powers of search given by the Gunpowder Act of 1860 were incorporated in this Act, which also contained a provision that in England and Ireland one-half

* Jones *v.* Cook, *Law Reports*, 6 Q.B. 505.

of any forfeiture or penalty should go to the informer, unless he were a servant of the person informed against.

No means of testing the flash-point were laid down, and the temperature in the definition was taken by some to mean that of the "fire-test" of the oil. In point of fact the Act was found to be unworkable, and though occasional prosecutions did take place, it may be said that practically it was wholly inoperative.

Select Committee of 1867.

In 1867 a Select Committee was appointed by the House of Commons to inquire into the then existing legislative provisions for the protection of life and property against fire. A great deal of evidence on the dangers of petroleum and the inefficient character of the legislation was taken, and the Committee presented a report in which a number of recommendations were put forward. One of these recommendations was to the effect that no petroleum with a flash-point of less than 110° F. should be sold for illuminating purposes, the flash-point to be determined by an open test, details of which were given. In this recommendation the Committee were following the lines of American legislation. In the United States a law had recently been passed prohibiting the sale of mineral oils below a fire-test of 110° F. for illuminating purposes, but such a prohibition is entirely contrary to the spirit of legislation in this country. An Englishman would very much resent being called upon to say for what purpose he was buying any particular article, and if asked by an oilman what he wanted petroleum for, he would probably suggest that the vendor should mind his own business.*

* This difficulty was to some extent met in the Bill brought in in 1868 by providing that a person would be deemed to be selling petroleum spirit for illuminating purposes unless the vessel was labelled: "The contents must on no account be used for lamps."

Obviously no total prohibition of the sale of petroleum below a certain standard could even be contemplated, inasmuch as mineral spirit is largely used in a variety of trades and by private persons for purposes of cleaning and as a solvent, to say nothing of its use in sponge- and flare-lamps, and more recently in motor-cars.

In consequence of this Committee's recommendations, a Bill was introduced in the following year, laying down a flash-point of 110° F. by the open test. Thereupon the Petroleum Association sent a deputation to the Home Office to urge that the flash-point should be fixed at 100° as before. In consequence of this the whole question was referred to a Committee, consisting of Sir Frederick Abel (then Mr. Abel), Professor John Attfield and Dr. Henry Letheby.

Report of the "three chemists."

On June 4, 1868, this Committee made a report to the Home Secretary which afterwards became known as the "report of the three chemists." While adhering to a flash-point of 100° F. as a safe limit, the three chemists proposed that the test should be carried out in an apparatus which they described, and which is known as the "open half-filled cup." This apparatus has been described in a previous chapter (p. 81). They also gave the results of some experiments with lamps, and proved that the production of an inflammable mixture in a lamp is not governed so much by the temperature of the oil as by the temperature of the metal work in contact with the wick, which temperature in the lamps experimented with rose as high as 113° F. They reported, however, that they did not consider it necessary to raise the legal flash-point above 100° F.

Immediately after this report had been made, the petroleum trade were communicated with, and submitted certain objections to the half-filled cup.

Sir F. Abel's alteration.

The matter was accordingly referred back to Sir F. Abel, who substituted for the half-filled cup a full cup

with a screen round it, and this was introduced into the Schedule of the Bill then before Parliament, which was recommitted on June 15, 1868. As to the exact difference between the results of the two forms of apparatus there has been much divergence of opinion,* probably on account of the fact that both forms are capable of manipulation, and are liable to give different results in the hands of different operators. The question is not really of the importance which it has been sought to attach to it, inasmuch as the test of the three chemists never at any time became the legal test.

In July 1868 the Act was passed. This amended the Act of 1862, and was intended to be read as one with the latter. The definition of petroleum was amplified, and was framed with the evident intention of restricting the application of the Act to petroleum below the specified flash-point, but the word "include" instead of the word "mean" still remained, so that it cannot be said with certainty that the heavier oils did not come legally within the scope of the Act. **Act of 1868.**

The flash-point was fixed at 100° F. as before, and the method of testing was specified in a Schedule to the Act. The method finally adopted was the open full-cup with a screen as proposed by Sir F. Abel. This must not be confounded with the Abel test.

* Dr. Attfield before the Select Committee of 1872 (Q. 770) stated that if the efficiency of the test recommended by the three chemists was to be maintained, the screen must be five inches in height, implying presumably that with a screen of that height the full cup would give the same results as the half-filled cup, whereas before the Select Committee of 1896 (Q. 4628) he stated that the half-filled cup gave a similar result to the Abel apparatus, *i.e.*, 27° lower than the full cup. Again in a report quoted by Sir F. Abel before the latter Committee (Q. 7162) Dr. Attfield stated that the open cup with a three-inch screen and a cover to the screen gives the same results as the half-filled cup.

In the Act of 1868, instead of a quantity not exceeding 40 gallons being allowed to be kept without licence within 50 yards of a dwelling house or warehouse, no quantity was allowed to be so kept, except for private use, in which case apparently an unlimited amount might be kept anywhere. Under this Act all petroleum spirit sold or exposed for sale was required to bear a label with an elaborate inscription upon it.

Provision was also made for the testing, by Inspectors of Weights and Measures, of petroleum kept for sale, with the curious anomaly that if the petroleum was found by the Inspector to be kept contrary to the provisions of the Act, the person so offending was liable to a penalty not exceeding five pounds, whereas by a preceding section a person keeping petroleum without a licence in contravention of the Act was liable to a penalty of twenty pounds a day.

Bill of 1869. In the following year a Bill was introduced into Parliament to repeal the previous Acts, and in this several new principles were embodied. The term "inflammable oil" was substituted for "petroleum," and the definition was drawn so as clearly to exclude all oil above 100° F. flash-point (open-test). The Bill was made to apply also to nitro-glycerine, to which apparently the officer of the local authority was called upon to apply the flash-test. Had this measure become law, local authorities might have found considerable difficulty in filling the frequent vacancies which would inevitably have occurred. Fortunately the Bill did not become law.

Nothing further appears to have been done until 1871, when a fresh Act was passed repealing the two previous ones. When this Act was first introduced as a Bill, it contained a close-test with a flash-point of 85° F.; but although it was generally admitted that this test was superior to that specified in the Act of

1868, there was a great difference of opinion as to the equivalent flash-point to be adopted for the close-test. The controversy on this point was so prolonged that though the Bill passed the Lords, the period of the Session was too late for the matter to be adjusted. Consequently the close-test was dropped, and the Bill was passed with the open-test as specified in the Act of 1868.

Act of 1871. The Act of 1871 was passed for one year only, with the intention of legislating further in the ensuing Session. It was, however, renewed annually until 1879, when it was made permanent, and is still in force, though the test has been modified. The details of this Act will be dealt with in the succeeding chapter.

Bill of 1872. In 1872 a Bill was introduced into the Lords to substitute the close-test, it being by this time generally acknowledged that the open-test specified in the Acts of 1868 and 1871 was a very uncertain one.

Select Committee of 1872. A flash-point of 85° F. was first adopted as the equivalent of 100° F. by the open test. The Bill was referred to a Select Committee of the House of Lords with a view to determining whether this equivalent was correct. This Committee collected a great deal of valuable evidence, and the question of flash-point was keenly fought before them.

On July 5 they finally agreed on their report, which was to the effect that the close-test, with an alteration in detail, was much superior to the open-test. They considered that a flash-point of 100° F. by the open-test was sufficiently high to guarantee the safety of the public, and that the equivalent by the close-test should be 82°, not 85° as prescribed. The Bill, however, was not brought down from the Lords until July 26, and it was then too late to make any further progress with it.

The subject of petroleum legislation was, shortly after this, taken up by the late Sir Vivian Majendie, who collected much information as to the working of the Act of 1871.

Test revised by Sir F. Abel.

In 1875 Sir F. Abel was asked to propose an improved method of testing, and on August 26, 1876, he made a report in which the Abel close-test was first brought forward. A full description of this apparatus will be found in Appendix II. A vast number of comparisons between the new apparatus and the old open-test were made by different persons and with different samples of oil, with the result that the mean difference was found to be 27° F., that is to say, that an oil which would flash at 100° F. in the apparatus specified by the Act of 1871 would give 73° F. in the Abel test.

A flash-point of 73° F. was therefore fixed for the Abel apparatus; but it must be distinctly understood that this does not imply that the standard was in any way lowered.

Act of 1879.

It was not until 1879 that the new test was at length adopted and made legal by an Act, which is still in force, being substituted for the test prescribed by the Act of 1871. The Act of 1879, beyond substituting the new test and making the previous Act a permanent one, went no further in amending the law, although by this time it was seen that several amendments might with advantage be made. These, however, were reserved for future legislation.

Hawking.

One of the most important defects in the law was the absence of regulation in the case of hawkers. Some years before this (July 26, 1875), the Law Officers had given an opinion to the effect that the Act of 1871 would not prevent the hawking of petroleum in any district without licence, if the petroleum was not kept in the same district; but on November 8, 1879, the Court of Queen's Bench decided in the case of Coleman

v. Goldsmith that petroleum could not be kept in a hawker's cart without licence, or, in other words, that a hawker's cart must be regarded as a place within the meaning of the Act. The previous decision had imposed a hardship on those who, having a fixed place of business, were obliged to take out a licence, while the peripatetic hawker was under no restriction, and might therefore undersell the licensed vendor. The reversal of this decision, however, introduced fresh difficulties. A hawker might ply his trade in half a dozen districts: to whom was he to apply for a licence, and what was he to do when the restrictions imposed in the different districts were not the same? It became necessary, therefore, to impose statutory rules to be complied with by all hawkers throughout the Kingdom, and at the same time to exempt their vehicles from the necessity of licence. In 1881 an Act was passed for this purpose, and this Act being still in force will be dealt with in detail in the next chapter.

Act of 1881.

The Act of 1881 dealt only with the hawker difficulty, and it was not till 1883 that an attempt was made to remedy the other admitted defects of the existing legislation. In that year a comprehensive Bill was introduced into the House of Lords, which repealed all previous Acts and introduced a new system of dealing with the whole subject.

Bill of 1883.

This Bill being a very long one, and containing no less than fifty-seven clauses, it is impossible to do more than glance at its more salient features. These were as follows:—The Bill was made to apply to all petroleum defined as before, whatever its flash-point; but two classes were recognised and designated "high-test petroleum" and "low-test petroleum," the dividing line being fixed at a flash-point of 73° F. (Abel). Excepting for private use petroleum was to be kept only on premises registered with the local authority.

Statutory rules were laid down to be observed on such registered premises, these rules being, of course, much more stringent in the case of low-test petroleum.

The place where the petroleum was kept was to be termed a "depôt," and the quantities which might be kept were to be regulated by the distance at which the depôt was situated from dwelling-houses, &c., the amount to be allowed in a dwelling-house being only 50 gallons. In every case the amount of low-test petroleum was to be only one quarter of the total amount allowed.

The Bill dealt with the conveyance of petroleum, and provided for the making of by-laws, not only by harbour authorities, but also by railway and canal companies. The hawking of petroleum was dealt with, and the powers and duties of local authorities were amplified and extended.

There was also a clause providing for inquiry on behalf of the Secretary of State into causes of accidents, together with a number of miscellaneous clauses not contained in previous legislation.

The description of the testing apparatus, printed as a Schedule in the Bill, was copied from that contained in the Act of 1879; but another Schedule had been prepared in which the description differed in certain minor details, and this was considered to represent the actual apparatus somewhat more exactly.

Select Committee of 1883.

The Bill was referred to a Select Committee of the House of Lords, who, having heard a great deal of evidence and a number of objections urged against the Bill, reported that they did not consider it expedient that it should be proceeded with, but that the evidence they had taken would enable a fresh Bill to be prepared for the ensuing Session. The Bill was accordingly dropped.

Shortly after this, the late Sir Vivian Majendie, in

company with one of the authors, then Secretary of the Petroleum Association, commenced a tour of inspection and inquiry in the United Kingdom and on the Continent, in the course of which a large number of places were visited.

In 1884 a draft Bill was in course of preparation, but did not reach the stage of being introduced into Parliament. In that year numerous conferences were held between the late Sir Vivian Majendie and the trade.

In 1886 the tour of inspection was extended to Canada and the United States, and towards the end of the following year the preparation of another Bill was in progress.

In the early part of 1888 more conferences were held, a large and influential committee, representing all branches of the trade, having been called together by the Petroleum Association. No opportunity for introducing the new Bill occurred in the two succeeding years, and it was not until February 9, 1891, that the measure was read for the first time in the House of Commons. An extensive memorandum on this Bill was prepared by the Home Office, and issued to both Houses of Parliament. Thereupon the Petroleum Defence Committee issued a report criticising the statements in this memorandum, evidently with a view to showing that such legislation was unnecessary.

Bill of 1891.

The Bill of 1891, like so many of its predecessors, died a natural death. It did not, in fact, reach a second reading. In general it followed the lines of the Bill of 1883, but it was made to apply not only to petroleum, as previously defined, but to liquid mixtures of petroleum with other substances, and to bisulphide of carbon also.

It was termed the Inflammable Liquids Bill. Such inflammable liquids as have a specific gravity exceeding 1·000, and a flash-point over 150° F. (Abel), were

excluded. The terms "mineral oil" and "mineral spirit" were substituted for "high-test" and "low-test" petroleum, the dividing line being, as before, a flash-point of 73° F. (Abel). Mineral spirit in quantity above three gallons was only to be kept under licence, but mineral oil, with an exemption of sixty gallons, might be kept either under licence or under registration; the rules to be observed and the quantities to be kept in the latter case being laid down in the Bill.

A table regulating the relation between quantity kept and distance from protected works appeared as a Schedule. In the case of licences, certain general rules to be observed were laid down, but power was given to the local authority to impose additional conditions. The Bill also contained a sort of instruction to local authorities not to be too hard on places which had been licensed under the Act of 1871, in cases where such places did not strictly conform with the new requirements. The expressions "depôt" and "tank depôt" were rigidly defined, the definitions in the former case being framed so as to provide against outflow, while the tank forming a tank-depôt was to be constructed in accordance with a specification laid down by the Secretary of State.

The Schedule containing the description and instructions for use of the testing apparatus was fuller and more accurate than in the Act of 1879, and a table of corrections for barometric pressure was added.

The remainder of the Bill was on the same lines as that of 1883, but it was even longer and more elaborate than the latter, and contained in all seventy-one clauses.

Flash-point agitation.

Up to this time there had been no suggestion that the standard should be altered, but in 1892 the Scottish oil producers commenced an agitation with a view to inducing the Government to raise the flash-point.

According to the evidence given by the general manager of one of the Scottish Oil Companies, before the Select Committee of 1894, action had not been previously taken in this direction owing to the existence of an understanding between the Scottish and American trades, by which the latter undertook to keep down the production of paraffin wax, on condition that the question of altering the standard of flash-point in this country was not raised.*

Select Committees of 1894 to 1898

In 1894 a Select Committee of the House of Commons was appointed, and after having taken a certain amount of evidence, recommended that the Committee should be re-appointed. In 1896 this was done, and the Committee which sat during that year and was again re-appointed in the following year, made their report in 1898.

It is impossible within the limits of this chapter to do more than glance at the immense amount of evidence collected by these Committees, though this evidence has been extensively made use of in other parts of this volume.

The statements of several of the witnesses were directed to showing the deficiencies in the existing law in regard to petroleum, and much valuable evidence on this point was supplied by the late Sir Vivian Majendie, who also furnished records of accidents which have occurred. The necessity of legislating for petroleum above the legal flash-point was very fully considered, as also the form which such legislation should take.

One group of witnesses sought to prove by their evidence that accidents would be largely or entirely prevented by the simple expedient of raising the flash-point to 100° F. (Abel).

The question of defects in the construction of lamps was entered into very fully, and some witnesses attri-

* Select Committee 1894. Question 597 *et seq.*

buted the majority of lamp accidents to these defects. Representatives of the lamp trades were heard, and some of them admitted that the construction of lamps should be improved. The views of municipal authorities were heard, as also those of the coroners of England. In general it may be said that the evidence represented almost every interest concerned. It need hardly be said, therefore, that the most conflicting opinions were expressed.

Had the Committee been able to present a unanimous Report, such Report would have been of immense value, and would have cleared up the whole question once for all. However, so far from the Report being a unanimous one, the Committee were almost equally divided for and against every recommendation. Indeed, whether any particular recommendation was put forward or not appears to have depended almost entirely on the number of members who happened to be present. As a consequence of this the Report contains contradictions, and is of very little value or guidance to the Government in framing fresh legislation.

In one part of the Report the Committee recommend that the flash-point should be raised to 100° F. (Abel), while in another they report strongly against such a measure. They recommend legislation based on the lines of the Bill of 1891 in regard to all oils, and statutory powers to be given to the Secretary of State to make regulations as to the manufacture and sale of lamps. They further suggest that steps should be taken to spread information among the public as to the nature of petroleum and the management of lamps.

Mr. Reckitt's Bill.

In the following Session a private Bill was introduced by Mr. Reckitt, a member of the Committee, to raise the legal flash-point to 100° F. (Abel). This Bill was rejected on its second reading by a large majority in a

full House. The amount of "lobbying" which had taken place on this occasion was such as to induce Mr. Healy, in a humorous speech, to express wonder whether "all this was pure philanthropy."

Meanwhile a Government Bill had been prepared in which an attempt was made to meet some of the more prominent requirements, but as yet there has been no opportunity of introducing it.

This brings the somewhat remarkable history of petroleum legislation up to the present date. In the main, it is a history of laborious attempt and discouraging failure. Committee after Committee have sat; volumes of evidence have been given and recorded; Bill after Bill has been prepared, only to be thrown aside; so that truly it may be said that, in the number of its failures, petroleum legislation rivals the Bill for legalising marriage with a deceased wife's sister.

CHAPTER VIII.

EXISTING LEGISLATION RELATING TO PETROLEUM.

Petroleum Acts, 1871 to 1881.

THE law in regard to petroleum in force at the present time is contained in the Petroleum Acts of 1871, 1879, and 1881. For convenience of reference these Acts, together with some explanatory notes, have been printed in Appendix II., the Act of 1879 being incorporated with that of 1871. In the existing legislation there is no prohibition of the importation, keeping, sale, or use of any particular description of petroleum, nor, with one exception, is there any restriction whatever which applies to mineral oils—*i.e.*, petroleum above the legal flash-point. The Acts merely impose certain restrictions on the importation, storage, and sale of petroleum spirit flashing below 73° F. (Abel). The fact that oils sold for use in ordinary lamps are always above this flash-point, has led some persons to suppose that the sale of petroleum spirit for this purpose is prohibited by law, whereas in reality this is only an incidental effect. At the present time there is little difference in price between oil and spirit, so that naturally the majority of traders stock only such oils as they are able to keep and sell without restriction. It is not impossible, however, that at some future time, owing either to alteration in the law or to other circumstances, this condition of things might be largely modified.

Petroleum spirit not prohibited for use in lamps.

If, for instance, it were found that either a better or much cheaper illuminant could be produced below

the legal flash-point, the demand for this would probably necessitate its supply, and both dealers and users might either submit to, or attempt to evade, restrictions in order to obtain a form of petroleum better suited to their needs. At the present time, however, petroleum spirit, though largely used for manufacturing and other purposes, is not in great demand as an illuminant; and the number of places licensed for its keeping throughout the kingdom is not very large.

Scope of Acts of 1871 and 1879.

The scope of the Acts of 1871 and 1879 may be briefly described as follows:

(1) To define petroleum, and to make the law applicable only to petroleum spirit having a flash-point below 73° F. (Abel). (1871, Sect. 2; and 1879, Sect. 2.)

(2) To lay down a detailed system of testing, and to provide for the verification of the test apparatus. (1879, Sect. 2 and 3, and First Schedule.)

(3) To provide for the making of harbour by-laws governing the berthing of ships carrying petroleum spirit and the landing of their cargoes, and to provide for notice being given to the harbour authority on the entry of such ships into a harbour. (1871, Sects. 4 and 5.)

(4) To provide for the marking of vessels containing petroleum spirit. (1871, Sect. 6.)

(5) To require that, with the exception of a quantity not exceeding three gallons when kept in a prescribed manner, no petroleum spirit may be kept without a licence from the local authority. (1871, Sect. 7.)

(6) To specify the local authorities throughout the Kingdom. (1871, Sect. 8.)

(7) To provide for the method of granting, and the scope of, licences for keeping petroleum spirit. (1871, Sect. 9.)

(8) To provide a right of appeal in cases where the grant of a licence is refused by the local authority,

or where an applicant is dissatisfied with the conditions imposed. (1871, Sect. 10.)

(9) To provide for the sampling, testing, and inspection of petroleum on dealers' premises. (1871, Sect. 11.)

(10) To provide a penalty for refusing to show petroleum, or for obstructing the officer of the local authority in the case of dealers. (1871, Sect. 12.)

(11) To provide means of search for, and seizure of, petroleum spirit in respect of which there is believed to be a breach of the law. (1871, Sect. 13.)

(12) To enable other substances to be brought within the scope of the Acts by Order in Council. (1871, Sect. 14.)

(13) To provide for the prosecution of offenders and the recovery of penalties. (1871, Sect. 15.)

(14) To provide for the reservation of previous powers with respect to inflammable substances, and for the repeal of previous Acts. (1871, Sects. 16 and 17.)

The detailed precautions to be taken in bringing petroleum spirit into the country, or in its storage, are not contained in the Acts themselves, but are to be enjoined by harbour by-laws or by the terms of licences granted by local authorities. Consequently these vary considerably in different places. In order to assist harbour authorities in framing by-laws in the future, the Explosives Department of the Home Office have recently, at the instance of the Board of Trade, prepared a Model Code, which will be found in Appendix V. This Code is, of course, in no way binding, and may be varied in accordance with local conditions or the requirements of any particular harbour.

Harbour by-laws.

In Appendix VI. will be found the forms of licence which are used by the London County Council to cover the various conditions under which petroleum is allowed to be kept in the Metropolis. These, again, are in no way binding on other local authorities, but may be of

Forms of licence.

assistance to those who have not already adopted a suitable form of licence. The London County Council have also issued, for the guidance of persons concerned, an abstract of the Petroleum Acts.

Verification of testing instrument.

After the passing of the Act of 1879, the Standards Office of the Board of Trade issued regulations as to the construction and verification of the apparatus for testing petroleum. These regulations will be found in Appendix VII., and a diagram of the instrument will be found in Plate II., Appendix II.

Carbide of calcium.

Two Orders in Council (Appendix XII.) have been made under Section 14 of the Act of 1871. The first of these brings carbide of calcium within the provisions of the Act, and the second exempts small quantities of this substance from the necessity of licence. These Orders will be referred to at greater length in chap. xi.

Scope of Act of 1881.

The Petroleum (Hawkers) Act, 1881, deals only with the hawking of petroleum spirit. This Act will be found printed in full in Appendix IV. Its scope is as follows:

(1) To enable any person licensed under the Act of 1871 to hawk petroleum. (Sect. 1.)

(2) To provide that petroleum oil while in any carriage used for the hawking of petroleum spirit shall be deemed to be petroleum to which the Petroleum Act applies, and shall therefore be subject to the same regulations. (Sect. 2.)

(This is the only restriction on petroleum oil which exists under present legislation, unless indeed there are any local Acts bearing on the subject.)

(3) To provide detailed regulations in regard to such hawking. (Sect. 2.)

(4) To provide for seizure of petroleum without warrant in a case where there is cause to believe that an offence against this Act is being committed. (Sect. 4.)

(5) To prevent the hawking of petroleum in any borough where such hawking has by lawful authority been forbidden. (Sect. 5.)

Defects in existing legislation.

Although undoubtedly the Petroleum Act of 1871 has many defects, the fact that it has remained upon the Statute Book—amended, it is true, by the two subsequent Acts—for thirty years may be regarded as a proof that it is by no means unworkable. Nor has it in any sense become a dead letter, though it must be admitted that in many places its administration leaves much to be desired. It has, at any rate, the merit of comparative simplicity, and the questions which have arisen in regard to its interpretation and effect have not been numerous.

It may not be out of place to discuss some of the defects, both real and alleged, which pertain to existing legislation, as well as proposals which have been made for their remedy.

The present Acts do not in any way control the keeping of petroleum oils, and various representations have been made to the Government in favour of subjecting such oils to legislative restriction. To meet this defect it has been proposed to adopt a system of registration of places where petroleum oil up to a flash-point of 150° F. (Abel) is kept.

This would not interfere with the right of any person to keep such oil so long as he observes certain statutory precautions; whilst in the event of his having a difficulty in observing these precautions, it was intended that he should still have the alternative of applying for licence to the local authority. On the other hand, it has been urged that if the legal flash-point were raised to 100° F. (Abel), it would be safe to exclude any oil flashing above that temperature from all restriction.

A minor defect is that the method of testing described in the Schedule to the Act of 1879 makes no

allowance for variations in barometric pressure, and that in other respects the Schedule is capable of improvement. In the Bill of 1891 a Schedule was inserted providing for an improved testing apparatus known as the Abel-Pensky,* in which there is a clock-work arrangement for applying the igniting flame. This Schedule also contained a Table of Corrections of flash-point for variations in barometric pressure. These corrections, which are given in Appendix VIII., have not yet been sanctioned by law, but it might be well for inspectors, in cases where petroleum of a flash-point but slightly below the legal standard is found to be kept, to refer to this table and ascertain whether, if the observed flash-point were corrected, the keeping would still be illegal or not, and use discretion as to the institution of proceedings accordingly.

Another defect is the very limited scope of the powers conferred on the harbour authorities in regard to by-laws. These powers do not directly include the regulation of the shipment of petroleum, or the enforcing of precautions on board the ship previous to landing the petroleum, or on a wharf after the petroleum is landed. It is doubtful even if all the by-laws in the suggested Model Code are strictly within the four corners of the Act, though it is probable that any Court of Law would hold that they are sufficiently within the intention of the Act to give them legal validity.

The absence of powers enabling railway and canal companies to make by-laws, and the omission of all restriction on the conveyance of petroleum spirit, is regarded as another defect in the law. But it must be remembered that, as railway and canal companies are not common carriers of dangerous goods, it is open

* For a description of this instrument (Capt. Thomson's petroleum spirit tester), see chap vi.

to them to impose such restrictions as will ensure safety, and that it is wholly to their advantage to do so.

The railway companies have, through their Clearing House, done a good deal in this direction, and quite recently they have consulted the Authors with a view to putting the whole question of the nature of vessels of all sizes for conveyance of petroleum spirit, including tank-waggons, on a more satisfactory footing.

Various experiments and tests of the smaller vessels have been carried out, and specifications of these and of tank-waggons have been recommended. These specifications will probably find a place in the publication* in which the railway companies specify their conditions for the carriage of goods classified as dangerous substances. As a matter of fact, serious accidents in the inland conveyance of petroleum have not been frequent, and it cannot be said that there is any urgent necessity for the amendment of the law in this direction.

Another defect in existing legislation is the absence of any definite regulations of universal application to the keeping of petroleum, and indeed of any indication as to the character of the precautions which should be taken, this being a matter left entirely to the discretion of the local authority.

The Acts are also defective in their provisions as to local control. They contain no obligation on the local authority to enforce the law or to appoint officers for the purpose.

The excessive decentralisation which puts in the hands of district councils throughout the Kingdom the administration of such technical legislation cannot but militate against the attainment of the object in view. In many cases it is impossible for these bodies

* General Railway Classification of Goods.

to find any person with sufficient technical knowledge to advise them, or to act as their officer in enforcing the provisions of the Acts. Nor are the present local authorities always fitted for the duty, inasmuch as their members are frequently interested parties and licensees under the Act.

Even where there is every desire to carry the Acts into effect and where a zealous and efficient officer has been appointed, difficulties are met with in the inadequate powers of inspection, search and sampling, particularly in the case of petroleum kept by persons who are not dealers. As an example, a recent case may be quoted in which an accident occurred with carbide of calcium on unlicensed premises. The officer of the local authority, wishing to inspect the place, found that in order to obtain the necessary search warrant, he would have to wait some weeks, until the next sitting of the bench of magistrates.

The absence of any provision for Government control and general supervision of the working of the Acts is undoubtedly also a defect. Under existing legislation there is no Government department having statutory powers under the Acts, nor has any Government officer a legal right of entry.

Other defects are the absence of a statutory requirement as to the reporting of accidents, and the want of provision for inquiry into those which are of a serious character.

Possibility of future legislation.

The majority of the above defects, as well as many others of less importance which have from time to time made themselves felt, will no doubt in time be remedied by fresh legislation of a comprehensive character; but it must be evident that at the present time, at any rate, the whole question has been so obscured by trade interests, and by prejudices which have been fostered thereby, that the Government would meet with the

greatest difficulty in passing even the most reasonable and moderate amendments of the law.

Exemption of petroleum spirit for light locomotives.

One further enactment bearing on petroleum should be mentioned. When the Locomotives on Highways Act, 1896, was under consideration, it was represented that, as many light locomotives would require for their use petroleum spirit, some relaxation of the law in regard to the keeping of such petroleum for this purpose might with advantage be made.

Consequently a provision was made in this Act for the Secretary of State to issue regulations under which petroleum spirit may be kept for use in light locomotives without licence from the local authority. An Order was made under this section on November 3, 1896, and this was superseded by an Order dated April 26, 1900. The latter is now in force, and will be found in Appendix IX.

CHAPTER IX.

PRECAUTIONS NECESSARY FOR PETROLEUM.

Comparative danger of oil and spirit.

In the previous chapter it has been pointed out that the law in this country in no way deals with petroleum oil —that is, with petroleum having a flash-point not below 73° F. (Abel). It must not be inferred from this that such petroleum is absolutely safe, and that precautions are therefore wholly unnecessary. The main difference between petroleum spirit and petroleum oil is that, whereas the former, as usually met with in this country, gives off vapour copiously at any ordinary temperature and is readily inflammable when brought in contact with a flame, petroleum oil gives off vapour sparingly, and does not take fire at ordinary temperatures unless it is absorbed in some material capable of acting as a wick. But when an ignition has taken place, the dangers are much the same whether oil or spirit is involved. Where oil and spirit are kept together, therefore, the whole should be regarded as though it were petroleum spirit.

The precautions which it is necessary to observe may be divided into two classes—viz., those for prevention of ignition, and those for minimising the effect of a conflagration should it occur.

Danger from naked light.

The most obvious precaution for the prevention of ignition is to prohibit the bringing of a naked light into dangerous proximity to the petroleum; but the question at once arises as to how dangerous proximity may be defined, and this will of course depend on

whether any petroleum spirit is present and also on the nature of the surroundings. The vapour from spirit, being heavier than air, has a tendency to flow, and an ignition may therefore take place at some distance from the bulk of the petroleum. This was well illustrated by an accident which occurred on December 22, 1882, at Exeter, when a rock-hewn store which had been shut up for some time, was opened in the early morning by a man who had previously placed his lantern on the ground at a distance of 53 feet from the entrance. The vapour travelled to the lantern and ignited, causing an explosion which was followed by a disastrous fire.

In a room where petroleum spirit is employed for the purpose of a trade or manufacture, it is not sufficient merely to provide that there shall be no naked light in the immediate vicinity of the spirit, but a fire or any light capable of igniting vapour should be excluded from the room altogether. With oil the danger of vapour ignition is much less, but is not entirely absent, as is shown by explosions which have occurred, notably one on May 17, 1884, on the British barque *A. Goudey*, and another at Harburg, near Hamburg, on May 31, 1895, where a tank containing oil was exploded by lightning. These, as well as several other explosions in America, were due to the vapour of oil and not spirit; but in each case the explosive mixture of vapour and air had formed in a tank or confined space, and the ignition took place at the tank and not at any distance away. In general, therefore, in the case of oil a naked light should not be taken into the immediate vicinity of the tank or vessel containing the oil, while in the case of spirit such light should never be taken into the building in which the petroleum is kept, or even into its vicinity, at any rate when the door is open. A store for petroleum spirit should only be entered during daylight,

or with some form of artificial light incapable of igniting vapour. For this purpose a Miners' Safety Lamp, or a special form of lamp constructed on the same principle, is sometimes used.

Lighting of spirit stores. Where a building in which spirit is used or stored is lighted by incandescent electric light,* special precautions should be taken in regard to the wiring and fittings, in addition to the regulations enjoined by the insurance companies. All switches and fuses should be outside the building, or should be enclosed in safety cases of metal or gauze. The wires should be led through metal pipes connected to earth, or should be protected by casing. No current-bearing part should be exposed—that is to say, all metal in contact with the source of electric supply should be either well coated with insulating material, or else entirely closed in a globe or metal case.

The Wenham Lamp Company have, at the suggestion of one of the authors, designed a gas lamp for the lighting of such buildings, which is so constructed that the air supply is brought in from the outside, and vapour cannot come into contact with the flame.

Some persons appear to consider that an ordinary closed lantern affords sufficient protection, but this is not the case. Unless a lamp is fitted with a properly constructed gauze covering to all apertures, it cannot with safety be taken into a building in which petroleum spirit is present.

Electric spark. The readiness with which petroleum vapour can be ignited by even a very small electric spark, has been shown by several accidents in factories where fabrics are treated with petroleum spirit for the purpose of cleaning or waterproofing.

In such cases the spark from the electric charge which had accumulated on the cloth was sufficient to

* The arc light could not, of course, be safely used.

ignite the vapour. An accident of this description occurred on December 14, 1893, at Bradford, in a process for waterproofing cloth by treatment with paraffin wax dissolved in petroleum spirit. On this occasion the question of the prevention of such accidents in future received a good deal of attention. Probably it would be impossible entirely to guard against this danger, but the chance of accident may be much reduced by artificial ventilation and by fitting fine wire brushes or series of needle points in close proximity to the cloth so as to remove the electricity by silent discharge.

Lightning. Every large tank, whether for oil or spirit, should be fitted with an efficient lightning-conductor, and it would be well if all petroleum stores were similarly protected. The number of serious fires and explosions of petroleum tanks, which have been caused by lightning in various parts of the world, is considerable, though fortunately in this country there has been comparative immunity from accidents of this description.

Leakage. It is most important at all times to guard against any leakage of petroleum, whether in conveyance, storage, or use. The neglect of this precaution has been a fruitful source of accident in the past. Thus at Mexboro' on May 13, 1881, oil stored in a yard had been allowed to leak into a cellar, where sufficient vapour accumulated to cause an explosion on a light being brought into the place. Again, the danger of allowing petroleum to leak or escape into the sewers has been illustrated by numerous accidents of a formidable character. For instance, on May 5, 1884, the roadway at Newport, Monmouthshire, was torn up by an explosion in the sewers due to a quantity of benzoline having been allowed to escape from a barrel in a shop. All taps for petroleum should be fitted with

drip-pans to catch any drip or leakage which may occur.

Tanks and vessels to be covered.

Every vessel, of whatever size, containing petroleum, whether oil or spirit, should have a cover. In the case of large tanks the cover may take the form of an air-tight lid or top, having no opening except a ventilating hole which should be covered with fine wire gauze. Petroleum in barrels should invariably be under a roof of uninflammable material. The fire which occurred at Broxburn on August 19, 1887, is an illustration of the danger of the contents of an oil-tank, the cover of which is imperfectly closed, being ignited by a spark from a chimney.

The necessity for a cover applies with equal force in the case of smaller vessels inside a building, as is shown by an accident at Hackney on June 17, 1896, where oil, which was being kept in open pails, became ignited, and a serious conflagration was caused.

Danger from empty barrels.

It is highly desirable that precautions should be taken to prevent children and unauthorised persons from having access to petroleum, or even to barrels in which it has been contained. Numerous explosions have been caused by mischievous boys applying lighted matches to the bung-holes of empty petroleum spirit barrels, which generally contain vapour and are always highly inflammable. Such barrels as well as all other material of an inflammable character should be kept as far distant as possible from the place where petroleum is stored. The fatal fire which occurred in Lambeth on January 26, 1893, was caused by the ignition of a quantity of inflammable rubbish which had been allowed to accumulate near a leaky oil-barrel.

Inflammable material.

Pouring petroleum on fires.

A fruitful source of accident, both in this country and abroad, is the foolish practice of pouring petroleum on a fire to make it burn up. This is frequently done with impunity, but the risk is never absent, and persons

indulging in the practice are liable at any time to meet with a painful death.

Quick-drying paints. Special precautions to prevent ignition of vapour should be taken in using the so-called quick-drying paints or paint-driers which usually contain petroleum spirit. Where these paints are used in a confined space, the conditions are highly favourable for the formation of an explosive atmosphere. The loss of H.M.S. *Doterel* in the Straits of Magellan on April 26, 1881, was due to an explosion of vapour from one of these paint-driers, known as Xerotine Siccative. The above are the more important precautions for the prevention of ignition; it remains to deal with those for minimising the effects of an ignition should one occur.

Ventilation. Every store in which petroleum spirit is kept in tanks should be thoroughly ventilated. This is not feasible where the spirit is kept in barrels, as it is found by experience that the effect of ventilation is to shrink the wood of the barrels and thus to increase the amount of leakage.

Sand for extinguishing fire. In every petroleum store, or in any shop where oil is kept, there should always be a quantity of sand in a large bucket or coal-scuttle, ready for throwing on to any petroleum which may be spilt and ignited on the floor. In this way a fire may be extinguished in its initial stage. It must be remembered that water is useless for this purpose, as the oil will float and continue to burn on the surface. In the case of petroleum being spilt and ignited in a room, or on the clothes of a person, the flames should be at once enveloped in a hearth-rug or woollen table-cloth.

Metal tanks. The safest description of vessel for containing petroleum, either in storage or conveyance, is undoubtedly a metal tank. It would be beyond the scope of this volume to enter into details of the

construction of tank-steamers or of tank-waggons for road or rail (though some particulars are given in chap. iv.); but specifications for storage-tanks, which it was proposed to prescribe by law, may be of assistance to local authorities in determining the suitability for licence of a proposed store for petroleum spirit. These specifications are given in Appendix X. Every tank, if not provided with a gauze-covered air-hole, should be fitted with some form of safety-valve to prevent its being burst by internal pressure when heated by a conflagration. In the disastrous fire which occurred at Walker Gate on January 29, 1898, eleven persons lost their lives and many more sustained injury owing to the bursting of a creosote tank made from an old boiler, which had become heated by the flames.

Precautions against outflow.

The most important precaution for minimising the effect of a fire is to prevent the outflow of the burning liquid. Thus every overground tank, every store for petroleum in barrels, and in fact every vessel containing petroleum oil or spirit, should be placed in such a position, or should be so surrounded with walls of masonry or earth, or with trenches, that under no circumstances can the liquid escape, even if the containing vessel gives way altogether. The capacity of the space formed by the surrounding wall, or of the trench, should be made sufficient to hold the contents of all the tanks or barrels which it surrounds. The effects of many of the largest petroleum fires have been aggravated by the outflow of the burning liquid into sewers, streets, or harbours, often with disastrous results. Thus in the accident at Exeter previously quoted, the burning petroleum flowed over the surface of the river and set fire to a vessel, which was completely destroyed. In December 1881, at Bristol, an oil-store took fire, and the burning oil ran down into

the sewers, causing great damage. Again, at Anderston Quay, Glasgow, on January 16, 1897, quantities of burning oil escaped and ran down the streets, damaging buildings and property. Underground tanks are the safest in this respect, as escape of the oil cannot occur, unless it is displaced by water intended to extinguish the fire, as was the case in an accident which occurred at Notting Hill on March 5, 1890. But where underground tanks are installed, the greatest care must be taken to prevent the oil percolating through the soil to a sewer or to some building, in the event of a leak occurring; and, whereas leakage from an overground tank is readily observed, it is difficult to detect escape where the tank is sunk in the ground.

Quantity in any one store.

The quantity of petroleum which should be kept in any one store should depend on the method of keeping, and on the distances from "protected works." In the Inflammable Liquids Bill, 1891, "protected works" were defined as buildings in which persons dwell or assemble, docks, wharves, timber-yards, other petroleum stores, and any other place which the local authority might require to be so treated. In Appendix XVI. will be found a notice of the distances which should be maintained whenever possible for various quantities and methods of keeping. Where petroleum is kept in a house it should never be stored in such a situation as, in case of fire, to prevent the escape of persons in the building. Three persons were burnt to death in the accident at Lambeth quoted above, their escape having been cut off by the burning oil, which was stored underneath the staircase. In general, the oil should be placed in the basement or outside the house, and in the case of shops it should be drawn to the place where it is wanted by a pump connected with the tank or barrel by means of a lead pipe.

Petroleum should never be kept or conveyed with

any explosive. It was the neglect of this rather obvious precaution which led to the disastrous explosion on the Regent's Park Canal on October 2, 1874. In that instance gunpowder and petroleum spirit were being conveyed in the same barge, and the vapour from the spirit found its way into the cabin where a fire was burning. The keeping of petroleum near explosives is prohibited by the Explosives Act, but notwithstanding this, it sometimes happens that a person ignorantly stores the two substances together, under the mistaken belief that in dealing with two dangerous things it is better to consolidate the risk.

Petroleum not to be kept or conveyed with explosives.

The precautions which have been enumerated refer mainly to the storage of petroleum; but many of them apply with equal force to conveyance. Thus the dangers of ignition and of leakage are as great, or even greater, when petroleum is being conveyed as when it is being kept in a place of storage. Until recently, accidents in the conveyance of petroleum by sea have been both serious and numerous; but it is to be hoped that as the proper construction of ships for this purpose is now better understood, and more rigorous attention is paid to harbour by-laws, accidents of this class will become less frequent. It has been pointed out in a previous chapter that harbour authorities have no power to make by-laws governing the shipment of petroleum; but this in no way relieves persons from the responsibility of adopting the same precautions in shipping as are enjoined in the landing of petroleum. (See Appendix V.)

Precautions in conveyance.

Special care must always be taken in cleansing the holds or tanks of vessels which have carried petroleum from all oil and vapour before a naked light is admitted, or before repairs are carried out. The best method of doing this in the case of tank-steamers is first to fill the tank up with water so as to float out all remnant

Cleansing the holds of petroleum ships.

of the oil, and then to pump out and thoroughly dry the tank. A powerful ventilating fan should then be applied, and should be kept working during the whole time men are working in the tank. Modern petroleum ships are usually fitted with a suitable fan for this purpose, but in some vessels a steam ejector is used for the purpose. Ordinary windsails do not furnish a very efficient means of cleansing a tank, and should not be relied on unless the conditions are exceptionally favourable for their use. Whatever the method of ventilation employed, the operation of cleansing is much assisted by injecting steam into the tank so as to warm the interior. That these precautions are necessary with vessels which have carried refined oil, as well as with those which have carried crude oil or spirit, was shown by the explosion which occurred in the s.s. *Petriana* on December 26, 1886, during repairs. This vessel had discharged a cargo of oil of a flash-point of 79° F. (Abel), and the tanks, having undergone repair, were being tested when a rapid ignition of the atmosphere in one of the tanks occurred, which caused the death of ten persons. In this case a spray of oil had in all probability been forced into the tank, but in the chapter on flash-point it has been pointed out that, under certain conditions, an explosive mixture of vapour and air may be formed by petroleum oil when at a temperature considerably below its flash-point.

It must be remembered that when a tank which has contained petroleum spirit is filled with water for the purpose of cleansing, a considerable quantity of vapour will be driven out; and in certain conditions of the weather this may tend to flow to some point where ignition could take place. Not only therefore must the requirement of the harbour by-law that no fire or light be on the vessel be strictly observed, but care

must also be taken that the position of the vessel at the time of cleansing is such that no danger can arise from neighbouring vessels or from any external source of ignition.

Conveyance by road and rail.

Of accidents in conveyance by road and rail there have not been a great number in this country, nor, with one exception, have they been attended by very serious consequences. The exception referred to is the accident at Abergele on August 20, 1868, when the Irish mail ran into a goods train carrying about fifty barrels of paraffin oil which was ignited, and thirty-three persons were burnt to death. It is doubtful whether any precaution would prevent an accident of this description. Where a train carrying petroleum meets with a serious collision, the petroleum will almost inevitably be spilt, and a fire will be very likely to ensue. In general, the vessels in which petroleum is conveyed should be of such substantial construction as to withstand rough usage, and even a mild collision, without allowing their contents to escape. A slight collision which occurred in shunting on the sidings of the Great Northern Railway on August 16, 1889, caused the breakage of some puncheons or large petroleum casks of insufficient strength containing mineral naphtha, and the spirit catching fire, the driver and fireman were burnt to death.

Over-filling of vessels.

An important precaution in the conveyance of petroleum is to avoid over-filling the vessel in which it is contained. The expansion of the liquid on rise of temperature, especially in the case of spirit, is considerable; and unless a sufficient air-space is left, this expansion will be liable to burst or strain even the strongest vessels. The amount of air-space which should be left ought never to be less than 5 per cent. of the total capacity of the vessel, and it would be better always to allow 7½ per cent.

Petroleum barrels to be covered in conveyance. Petroleum spirit in barrels, when conveyed in open trucks or lorries, should be covered by a tarpaulin to avoid the danger of ignition, in case of leakage, by a spark from without.

Drivers of waggons carrying petroleum spirit should not be allowed to smoke or even to carry matches, and such waggons should only travel during the hours of daylight. A driver should be in constant attendance on his waggon at all times when the latter is on a public thoroughfare, and should take every precaution to prevent mischievous persons approaching his vehicle, especially when leakage or spilling of the spirit may have occurred. In an accident which occurred at Hackney on January 6, 1880, a van loaded with petroleum spirit caught fire in the street from some cause which was not ascertained, and the burning liquid escaped, to the great danger of surrounding houses, several of which were scorched. Again, on December 20, 1898, in Great Russell Street, a man deliberately threw a lighted match into some spirit which had been spilt from a cart, with the result that the cart and all the naphtha were destroyed.

Fortunately, accidents in the conveyance of petroleum by canal have not been numerous. The Regent's Park explosion originated in the ignition of benzoline vapour, but in that instance a large quantity of gunpowder was also present. The vapour penetrated into the cabin of the barge, and was there by some means ignited. As it would be impossible in canal barges of ordinary construction absolutely to prevent such penetration of vapour, all fires and lights should be excluded from barges carrying petroleum spirit. As in the case of conveyance by road, petroleum, whether oil or spirit, should be covered over so as to protect it from ignition from without.

The hawking of petroleum spirit is provided for by

the regulations contained in the Act of 1881, and it is not necessary here to amplify the precautions enjoined by that Act. The hawking of petroleum oil is subject to no legal restrictions, but as will have been gathered from the preceding pages, precautions should not be altogether dispensed with. It is true that in an open cart there is little fear of vapour accumulating in the case of oil; but where a tank-waggon is employed, it is possible that under certain conditions an explosive atmosphere may be formed inside the tank, and a naked light should never therefore be brought near to the opening. In general, the precautions to be taken in hawking oil for the prevention of ignition and escape of the liquid, should be substantially the same as those detailed above for the storage and conveyance of this form of petroleum.

Hawking of petroleum.

The consideration of the dangers of petroleum lamps and the precautions to be taken in their use, will be left to the succeeding chapter.

Danger of suffocation.

One further danger should be mentioned, namely, the risk of suffocation to a person entering an atmosphere highly charged with petroleum vapour. The vapour is not actively poisonous, and may be inhaled in small proportions with perfect impunity; but like many other non-poisonous gases, it will, in large quantities, so vitiate the air as to deprive a human being of the necessary supply of oxygen. In a recent case which occurred at Todmorden, a man, contrary to orders, entered a tank which had contained naphtha, and was so far overcome by the vapour that he perished before assistance could be rendered. Cases of partial suffocation have occurred amongst men working in the holds of vessels carrying petroleum spirit in barrels.

To avoid this danger, tanks should not be entered except in cases of strict necessity, and then only after

being thoroughly cleansed of all remnant of spirit and vapour. The hold of a vessel and any other place where vapour is likely to have accumulated, should be well ventilated both before men begin to work therein and during the time they are so working. As regards ships this precaution is enjoined in most cases by harbour by-laws. The method adopted in testing the atmosphere of the tanks to ascertain whether vapour is present, is described in chap. vi. (p. 118).

CHAPTER X.

PETROLEUM OIL LAMPS.

It would be beyond the scope of this volume to attempt to describe the numberless forms of lamps designed for use with mineral oil. The different patterns actually in use in this country may be counted by hundreds, and a still larger number of those which have been unsuccessful or have achieved no sale may be found in the records of the Patent Office.

General construction.

In general, a petroleum lamp consists of an oil-container usually mounted on a pedestal, a burner through which the wick passes, and a chimney to create the draught necessary for the effective burning of the oil. Except as regards a few patented lamps, the design is simple in the extreme; yet it is upon the many details of construction that not only the efficiency of the lamp, but its safety in ordinary use, may depend.

Choice of a lamp.

Few persons have sufficient technical knowledge to judge of the safety and efficiency of a lamp, seen for the first time in the dealer's shop; and purchasers are often guided more by the beauty and finish of an article than by any consideration as to its efficiency or safety. It is well, therefore, to point out that in the case of petroleum lamps a beautiful appearance, even when accompanied by apparent excellence of manufacture and perhaps a high price, is not always a guarantee that a lamp will prove satisfactory in actual

use. Artistic effect may be dearly purchased if it is given by a lamp which blackens the ceilings, fouls the atmosphere, and above all has features which may tend to produce a serious accident.

On the other hand, the poorer classes are guided more by the question of cost than by any other consideration. To them the difference of a few pence in the price of a lamp is a matter of importance; and though they may also be influenced by the appearance of the lamp which they select, the question of safety seldom carries much weight. The importation of very cheap foreign lamps obliges British manufacturers to compete in prices, and to disregard some of the most important conditions of safety. The publicity which has recently been given to the whole subject of accidents with petroleum lamps, appears to have had the effect of making all classes more careful in the use of such lamps, and it is to be hoped that this publicity will also diminish the demand for the cheap and trumpery lamps which have been the cause of so many disasters.

Points of efficient construction.

Stability.

The following are the principal points which should be looked to in selecting a petroleum lamp. The base should be of such diameter or weight, in proportion to the height and weight of the whole lamp, that the lamp is not easily overturned. This can readily be tested by gently tilting the unlit lamp, and ascertaining at what angle it tends to fall over on its side. Any person of ordinary intelligence will then be able to judge whether or not the lamp is too top-heavy, and too liable to be upset in ordinary use. It must be remembered in carrying out this test with an empty lamp, that allowance must be made for the extra weight of the oil, and of any shade which it may be proposed to add; and that any tendency to instability in the empty lamp may be increased to a dangerous extent when the oil and shade are added.

The next point is to see that the oil-container is firmly fixed to the pedestal. Lamps constructed to fit into ordinary candlesticks should never be purchased, as, unless the fit is exact, there will always be a tendency for the lamp to be shaken off. Even when such lamps fit accurately, an ordinary candlestick forms a very insecure base when the weight of the lamp is added.

Oil-container.

One of the most important points to be looked to in choosing a lamp is the strength of the oil-container. This part should be sufficiently strong to withstand a fall on a bare wooden floor from the height of a table without either being broken or allowing the oil to escape. Oil-containers are usually made of either metal, glass, or porcelain. If of metal, the thickness of the walls should be such that there is no appreciable tendency to collapse when the container is squeezed with moderate force by the hand. Some of the cheap lamps now in the market are made of metal which is so thin that the oil-container can be readily crushed by the fingers without any great muscular effort. Such lamps would undoubtedly be dangerous when upset even from the height of a table on to the floor of an ordinary room. The joints of metal containers should be made by folding the edges of the metal over each other, and should be strongly soldered.

Glass or porcelain containers should be of substantial thickness to withstand the shock of a fall. A good rule is that the weight of a glass container should be from 15 oz. to 1 lb. for each pint of capacity. The substantial cut-glass containers fitted to the higher-priced lamps will generally be found to conform to this rule; but there are unfortunately large numbers of lamps on the market of which the containers are made of thin blown porcelain glass. These

so-called "egg-shell" lamps, though attractive in appearance, have been responsible for a large number of accidents, and it would be well if their use could be absolutely prohibited.

There has been much controversy as to the relative safety of metal and glass oil-containers. Undoubtedly a well-made and substantial metal container is safer than any glass one in the case of a fall; but it is contended that metal has a greater tendency to heat the oil, and is therefore more likely to produce a lamp explosion. This contention is not, however, borne out by actual experience. Mr. Spencer, in a report to the Public Control Committee of the London County Council, has shown that the number of lamp explosions which have occurred with glass reservoirs far exceeds that with lamps wholly of metal. It is true that glass containers are more commonly used than metal ones, but this is hardly sufficient to account for the large difference in the numbers. It is possible that explosions occur as often or oftener in metal containers, but that their consequences are seldom of a serious character.

One advantage clear glass containers certainly have over metal ones; and that is the opportunity they afford of seeing the level of the oil, and ascertaining at a glance whether the lamp requires replenishing or not. There is therefore less temptation to remove the burner whilst the lamp is lighted. There is not in reality much difference in point of safety between substantial containers of glass and those of metal. In either case, if the lamp is otherwise of proper construction and properly looked after, accidents are not likely to occur.

Filling-hole. Some lamps have a separate filling-hole for replenishing the oil, closed generally by a screw plug, but this opening is unnecessary, and its presence

offers a temptation to replenish the lamp without first extinguishing it. If a filling-hole is provided, the closing plug should have a well-fitting screw, and if this plug is perforated for an air inlet, the perforation should not be larger than a pin-hole.

Burner.

In the case of a metal lamp, the collar into which the burner is fitted should be securely soldered or brazed to the container; and where the latter is of glass or porcelain, the metal collar holding the burner should be firmly cemented to the container by means of a mixture of plaster-of-paris and glue or other suitable cement.

The burner should be attached to this collar by a well-fitting screw having at least three complete threads, or by a good bayonet joint. It is particularly in respect of the attachment of the burner that so many cheap lamps are defective. In some a screw stamped in thin metal, and having perhaps not more than one or two threads, is employed: in others there is a bayonet joint of equally flimsy construction. The consequence is that in a very short time the attachment becomes absolutely ineffective, and the burner is liable to be shaken loose by the smallest vibration. Then if a fall of the lamp occurs the burner is detached, and the oil, flowing out, becomes ignited, often with fatal result.

Several fatal accidents have occurred through the use of small glass lamps which are sold for a penny, and on which the burner is fitted without proper attachment. Such lamps are dangerous and should not be used for any purpose.

The thickness of metal of which the burner is constructed should be sufficient to prevent any tendency of the parts to be bent out of shape in the ordinary operations of cleaning and inserting the wick, even in not over-gentle hands, but should not be unnecessarily

great, as thick metal is less readily kept cool by air-currents. The wick-tube should be solid-drawn, brazed, or double-folded; and should be securely and completely soldered or brazed to the burner. The burner should be easily taken to pieces, so as to enable all parts to be readily cleaned. Above all, there should be no opening through which the explosive atmosphere which is liable to form in the container of any lamp can possibly be ignited. It is doubtful whether an air-inlet hole is ever necessary; but if this is provided, it should take the form of a mere pin-hole placed as far from the flame of the lamp as possible.

Chimney gallery. The chimney gallery is usually made of brass, and has projections turned up so as to hold the chimney. These projections should be made of substantial and elastic metal to afford a good grip for the chimney. If thin and weak, they soon get bent out and lose their hold, with the result that the chimney is liable to be tilted and cracked by the flame.

Wick-tube. There is some difference of opinion as to the value of an elongated wick-tube reaching down into the oil in the reservoir. It is claimed for this contrivance that it prevents the possibility of the ignition of the vapour in the container through the wick-tube; but if the wick entirely fills the tube, as it should do, no such ignition is possible. This elongated wick-tube has the disadvantage that it tends to heat the oil, and also renders the insertion of a fresh wick more difficult.

Safety lamps. Many safety devices for petroleum lamps have been proposed, and it would be beyond the scope of this volume to attempt to describe these in detail. The majority of such devices take the form of automatic extinguishers, which are intended to act when the lamp is upset or tilted out of the vertical. Few of these inventions can be wholly relied upon; and never should such reliance be placed on any so-called safety

lamp as to cause ordinary precautions to be regarded as unnecessary. An appliance for extinguishing the lamp when its light is no longer required is certainly a useful adjunct, and removes all inducement to adopt the dangerous practice of blowing down the chimney.

Management of lamps. More important even than the proper construction of the lamp is carefulness and intelligence in its management and use. The ordinary petroleum lamp is not such a complicated piece of mechanism as to require special intelligence for its safe employment, nor, on the other hand, is it so simple as to render all care and intelligence unnecessary. Any person who is not mentally deficient is perfectly capable of mastering the simple precautions which should be observed; yet so long as lamp users fail to grasp the necessity of these precautions accidents will continue to occur. Some local authorities and lamp manufacturers have done good work in preparing and distributing rules for the guidance of users of lamps, but more widely spread instruction is badly needed. It has been suggested that girls should be taught at the board schools the proper care and management of lamps. If this suggestion were carried out, there is little doubt that lamp accidents would become less frequent. In Appendix XI. will be found a code of rules based on those issued by local authorities, and embodying the precautions for the prevention of all the commoner forms of lamp accident.

Accidents. Dealing next with the subject of the accidents themselves, it may be said at once that the number of cases where death or personal injury has been caused appears at first sight very alarming. During the eight years from 1889 to 1896 inclusive, the number of fatal lamp accidents was 1031, making an annual average of 129 throughout the country. It must be remembered, however, that these deaths occurred

among a vast number of persons using petroleum. It has been estimated that the number of lamps burning every night throughout the country is upwards of 10,000,000, and this represents the lighting, burning, and extinguishing of a lamp nearly 4,000,000,000 times in a year. That this vast number of separate operations causes not more than 129 deaths tends to show that the danger to an individual in using a petroleum lamp is not as great as it is sometimes represented. It is instructive to compare the number of fatal accidents caused by lamps with that of deaths from some other accidental cause—as, for instance, from falling down stairs. During the period named above this latter class of accident accounted for no less than 5500 deaths, or more than five times as many as those due to lamp accidents. From this it will be seen that, large though the number of fatal lamp accidents undoubtedly is, it is not so much out of proportion to other fatalities as to call for legislation of a very drastic character.

Lamp explosions.

In considering the causes of the accidents which occur, one is met by the great difficulty in some cases in obtaining trustworthy evidence as to particulars. Until recently, nearly every mishap with a lamp was described as an explosion. On the other hand, witnesses before the Select Committee have given the opinion that true lamp explosions scarcely ever occur; this opinion being no doubt based on the difficulty of producing such an explosion experimentally.

The truth is that from 20 per cent. to 25 per cent. of the cases which have been investigated have proved to be explosions, whilst the remainder were fires caused in most cases by the fall of a lamp. A true lamp explosion occurs when the proportion of vapour to air in the reservoir happens to be between 2 per cent. and 4 per cent., and when at the same time the flame is brought in contact with the mixture. If the reservoir

is a fragile one it gives way, and the burning oil is thrown over any person who happens to be near. It is by the burning oil and not by the violence of the explosion that persons are killed and injured.

Falls of lamps. Falls of lamps occur in a variety of ways. Sometimes a person carrying a lamp stumbles or is jostled against: sometimes a lamp is pulled off a table or the latter is upset: hanging lamps are sometimes insecurely suspended: and sometimes a lamp is used as a missile.

Again, cases have occurred where a lamp which was being carried in the hand has suddenly flared up, with the result that the person carrying it has dropped it in alarm.

Another class of accident is caused by the ignition of the oil in attempting to refill the lamp while it is alight or in close proximity to a fire. In such cases a person loses presence of mind and upsets the burning oil.

Suggested legislation. It is doubtful as to how far the number of lamp accidents could be diminished by any legislative measure. The two suggestions which have been made as to legislation with this object are, first, to raise the flash-point to 100° F., and secondly, to establish a legal control over the construction of lamps.

Effect of raising the flash-point. The first suggestion has been mentioned in previous chapters (pp. 75 and 144). It is urged that by this means explosions would be entirely prevented, inasmuch as the temperature of the oil in the reservoir of a lamp seldom attains 100° F. It has been shown that this contention is erroneous (chap. v.). The conditions in the lamp are entirely different from those in the testing instrument, owing principally to the heated metal of the burner. Professor Dewar * has shown that, under ordinary conditions of burning, the metal work of the burner inside the oil-container is

* Select Committee, 1896; Q. 6758 *et seq.*

liable to acquire a temperature as high as 149° F., while if the draft is impeded, this temperature may rise still higher. Therefore, if the flash-point of the oil alone were to be depended upon, absolute immunity from lamp explosions could not be attained unless only oil of a much higher standard were employed. As to what this figure would be, opinions differ, but probably it would not be less than 150° F. (Abel), a flash-point which is quite out of the question, with the present construction of lamps, and sources of supply of oil.

Moreover, if the flash-point were raised there is no certainty that only oil above the legal standard would be employed, for it must be clearly understood that there would not, nor ever could be, in this country, a total prohibition of the sale and use of any particular description of petroleum. It is true that at the present time the effect of the restrictions placed on petroleum below a flash-point of 73° F. (Abel) has been almost entirely to abolish the use of spirit as an illuminant. Spirit now, however, costs more than oil, and there is therefore no inducement to any one to use the former in preference to the latter. If, however, the flash-point were raised, all this might be changed, and oils with flash-points below the legal standard might be found to be much cheaper and better illuminants. In such case it is unlikely that legislative restrictions would any longer serve as a deterrent to the use of lower flash-point oils.

The effect of the use only of oils of a flash-point above 100° F. (Abel) in preventing accidents from falling lamps is by no means certain. If a lamp falls on a carpet and the oil escapes, a conflagration may ensue, whatever the nature of the oil, unless the lamp happens to be extinguished. But it is urged that the rapidity of the combustion will be much less in the case of high-flash oil. Other conditions being alike, this contention

is perfectly true, and in this respect the higher the flash-point the greater will be the safety. But if in the struggle to supply a high-flash oil at a reasonable price the free-burning qualities are sacrificed, this advantage may be largely nullified. An oil which is sluggish in ascending the wick tends to heat the lamp unduly; and if when the lamp is upset the high-flash oil has become much hotter than would have been the case with oil of the present standard, there will be little difference in the rapidity of the resulting conflagration.

It is stated by those in favour of raising the flash-point that lamp accidents with high-flash oil are practically unknown. Even if this were true, it would not be conclusive as to the absolute safety of this description of oil, for two reasons. In the first place, the flash-point of the oil involved has not been ascertained in the case of the majority of lamp accidents which have occurred; and secondly, high-flash oil has not until lately been used to any large extent by the classes amongst whom the greater proportion of accidents occur. In the last two years, however, a brand of oil flashing at about 100° F. (Abel) has been sold at prices which have brought it within the reach of such classes, and accidents with this oil have occurred. Indeed the proportion of such accidents to those with low-flash oil appears to be somewhat greater than might be expected from the relative proportions in which the two oils are used amongst the poorer classes. It would not be safe, however, to draw conclusions from this fact, owing to the large number of cases in which nothing is known as to the quality of the oil.

Immunity from accidents in Scotland.

A more powerful argument in favour of a higher flash-point is the comparative immunity from lamp accidents in Scotland, where Scottish shale oil is principally used. But here again some other cause must

be operating to reduce the number of accidents, as the recent large increase in the consumption of low-flash oil in Scotland does not appear to have led to any increase in the number of lamp accidents. Moreover, in Germany and Switzerland, where the standard is lower than in this country, the number of accidents is also smaller than in England.

It is, therefore, by no means certain that raising the standard would have an appreciable effect in rendering lamp accidents less frequent.

Effect on price of oil.

An important consideration to be taken into account is the effect which the raising of the flash-point would have on the price and quality of the oil if such a measure attained the desired effect of preventing the use of low-flash oil as an illuminant.

It was shown above that fatal lamp accidents are largely outnumbered by fatal falls down stairs. Yet the most advanced reformer would not venture to suggest legislation for the abolition of houses of more than one storey. Obviously public safety is not the only consideration to be taken into account. Petroleum is essentially the illuminant of the poorer classes. The additional safety to be attained by raising the flash-point, the amount of which at best is somewhat doubtful, would be dearly bought if it entailed a serious increase of expenditure to the classes who can least afford it.

The exact increase in the price of oil which would result from legislation raising the flash-point to 100° F. (Abel) can only be a matter of conjecture, owing to the numerous conditions on which the price depends. The evidence on this point before the Select Committee was of the most contradictory character, and is therefore of little guidance as to the probable increase.

The Committee, however, have reported that the

effect of such legislation would be to materially increase the cost of petroleum to the consumer.

In attempting to arrive at an estimate, several considerations must be taken into account. At the present time Scottish oil, having a flash-point of over 100° F. (Abel), is somewhat lower in price than American low flash-point oil, while the so-called "Water-White," which is the high flash-point oil imported from America, costs wholesale a little over a penny a gallon more than the ordinary American oil.

But Scotch oil could never be produced in anything like the quantity which is required in this country. Nor would the supply of American Water-White oil be sufficient for our needs, inasmuch as this brand represents but a small percentage of the crude oil as taken from the wells.

It is possible, however, to refine the ordinary oil so as to bring the flash-point up to 100° F. (Abel.) This may be done by distilling off a certain percentage of the lighter petroleum; but in order to maintain the same free-burning qualities, it is necessary to remove also some portion of the heavier oils.

The results of laboratory experiments having for their object the raising of the flash-point of the ordinary oils of commerce, are not conclusive, as high-test oil would not in practice be made from low-test oil, but would be produced direct from the crude oil. It is therefore difficult to say what proportion of the ordinary oils at present made would be rejected in making oils of 100° flash-point. It may be assumed, however, that if the free burning quality is not sacrificed the diminution in yield would not be less than 10 to 15 per cent. and might be more. Extra capital expenditure would be necessary at the refineries to maintain the output, but, except for this, the additional cost of the refining operations would not, probably, be

appreciable, as it would be necessary only to carry the process of distilling off the spirit a little further, and to arrest the distillation of the kerosene at an earlier stage.

Conflicting opinions were given before the Committee as to the value of the portions of the ordinary American oil which would be thus rejected, but it seems probable that the portions in question could only be sold as a cheap fuel oil or for gas-making, and that their commercial value would be very low. Assuming this to be the case, the increase in the cost of the high-test oil over that of the low-test oil would probably result in the addition of not more than a penny a gallon to the price in this country, as the loss must be calculated on the oil at the refinery, where the price is comparatively low. It must, however, be borne in mind that there would be an increase in the quantity of by-products, of which at present the production in the United States is in excess of the market requirements, and that this would tend to further raise the cost of the high-test oil, as the surplus of these by-products could only be sold, if at all, at reduced prices.

There is, however, a more important point to be taken into consideration. According to evidence given before the Select Committee, the American refiners are barely able on the existing basis to meet the demands of the world for illuminating oil, and if the yield of such oil were diminished by raising the standard there would obviously be a risk of the supply proving inadequate. If this were to occur there would inevitably be a serious rise in prices, or in the alternative an equally serious falling-off in the quality of the oil. The extent to which this might occur cannot be estimated, and it is evident that advocates of a test-standard of 100° F. might, if successful in their

efforts, find that they had assumed a very great responsibility.

Prohibition of dangerous lamps.

The other direction which has been suggested for legislation would be more likely in time to produce good effect, and it is one which was recommended by the Select Committee with some approach to unanimity. Unquestionably if an Act of Parliament were passed which would have the effect of entirely preventing the use of defective and flimsy lamps, a large proportion of accidents would be avoided. But here again there are difficulties. Of the ten million lamps now in use in this country a large proportion are defective, and no law can prevent the continuance of their use. Again, a lamp which is up to the standard when it is first sold may become defective from old age or improper use, and here also the law would be powerless. Another obstacle would be the difficulty of ensuring an efficient administration of any such Act. Few local authorities in country districts would be able to find an inspector with sufficient technical qualifications to judge whether lamps which are offered for sale come up to the required standard. Even in large towns the local authority is not always sufficiently energetic to carry a law of this kind into useful effect. And if in any town cheap and defective lamps were allowed to be sold with impunity, ignorant persons from the whole district round would avail themselves of the opportunity, and the trade of the more law-abiding dealers would suffer.

Importance of instruction.

It will be seen from the above considerations that there are grave difficulties in the way of the prevention of accidents by legislative control. The surest method of diminishing the number of accidents would undoubtedly be some form of education by which persons of every class throughout the country would be induced to purchase only lamps of safe construction, and to use

them properly. The cure really lies with the people themselves, and no legislation of any kind can possibly be as effective as instructed popular opinion.

It is not too much to say that ninety per cent. of the accidents which have occurred, whether by explosion of a lamp or otherwise, have been directly due to gross carelessness, ignorance, or the use of lamps after they have become dirty or broken or defective, these causes being aided by the mistaken economy which induces persons to buy cheap and flimsy lamps rather than those of safer and at the same time more durable construction.

CHAPTER XI.

CARBIDE OF CALCIUM AND ACETYLENE.

Manufacture of carbide.

WHEN a mixture of lime and coke or other form of carbon is subjected to the intense heat of the electric furnace, chemical action takes place between the two substances. The lime is separated into its two component parts, calcium and oxygen, which combine with the carbon to form carbide of calcium and carbonic oxide respectively. The latter passes off as a gas, whilst the carbide remains in a molten or half-molten condition, and is either run off or allowed to form itself into an ingot in the furnace.

A very large amount of electrical power is required for the manufacture of carbide on a commercial scale, and for this reason factories for its manufacture are usually situated at places where water-power is available.

Formation of acetylene.

The importance of carbide of calcium as a commercial product lies in the ease with which it can be made to generate acetylene, which of all gases has the highest illuminating power. In order to produce this gas it is only necessary to bring the carbide into contact with water in a suitable generator, whereupon the calcium combines with the oxygen of the water to form lime, whilst the carbon combines with the hydrogen to form the gaseous product acetylene. The chemical processes involved in the formation of carbide of calcium and acetylene may be readily understood from the following simple chemical equations :

Making use of the usual symbols :

Calcium . .	Ca,	Carbon . .	C,
Oxygen . .	O,	Hydrogen .	H,

we get the following equations :

$$\underset{\text{Lime.}}{CaO} + \underset{\text{Carbon.}}{3C} = \underset{\text{Calcium Carbide.}}{CaC_2} + \underset{\text{Carbonic Oxide.}}{CO.}$$

$$\underset{\text{Calcium Carbide.}}{CaC_2} + \underset{\text{Water.}}{H_2O} = \underset{\text{Acetylene.}}{C_2H_2} + \underset{\text{Lime.}}{CaO.}$$

Affinity of carbide for water.

So great is the affinity of carbide of calcium for water that it combines with the moisture of the atmosphere, and whenever exposed to the air it continues to give off the highly inflammable gas.

This affinity is taken advantage of in what is termed the dry process of acetylene generation. The process in question consists in mixing powdered carbide with a salt, such as carbonate of soda, also in powder, which contains a large amount of water of crystallisation. The carbide then abstracts from the salt the water necessary for its decomposition.

Properties of carbide.

In appearance freshly broken carbide is a crystalline semi-metallic-looking solid. The fresh fracture is dark in colour, varying between brown and bluish-black, but is sometimes tinged with iridescent colours. When the surface has been exposed to the air, however, it becomes covered with a coating of lime which gives it a grey or whitish appearance.

Identification.

Carbide may be easily identified by plunging a small sample into water, and applying a match to the surface. If copious bubbles of gas rise in the water and are ignited on contact with the flame, and if a white powder is left at the bottom of the water, the sample may be pronounced to be carbide of calcium.

Properties of acetylene.

Acetylene gas has a disagreeable smell resembling that of garlic ; and to any one familiar with this smell carbide, which is exposed to the air, can be readily

identified without submitting it to the above test. The disagreeable odour is due to phosphoretted hydrogen, an impurity which is always present in acetylene made from commercial carbide. Perfectly pure acetylene has a rather pleasant etherial odour. The evil smell of the commercially formed gas is not altogether a disadvantage, inasmuch as it enables a leakage to be detected with even greater readiness than in the case of coal-gas.

Freed from impurities, acetylene is not a poisonous gas, though of course if air containing a very large percentage were breathed for any length of time, suffocation would ensue. Good commercial carbide will give about five cubic feet of acetylene per pound under suitable conditions of generation, but it is seldom in actual practice that the amount reaches this figure. Acetylene has a specific gravity of about 0·9, and therefore differs but little in weight from air. Consequently it mixes readily with the atmosphere, and shows no tendency to flow like the heavier vapour of petroleum.

Like all other inflammable gases and vapours, it tends to form an explosive mixture with the atmosphere. This mixture commences to be explosive when the proportion of acetylene reaches 3 per cent., and continues to be so under certain conditions until the proportion of gas is over 80 per cent. The maximum explosive force is reached when the proportion of gas to air is half and half. In this wide range of explosive capability, acetylene differs greatly from most inflammable gases, the reason being that it possesses explosive properties in itself without any admixture of air. When raised to a pressure of two atmospheres or even less, acetylene alone will, on the application of a light or spark, explode with very great violence.

The igniting temperature of acetylene in air is

896° F., which is somewhat below that of the visible red heat of iron, and is considerably lower than the igniting point of coal-gas or petroleum vapour. The temperature necessary to produce an explosion of compressed acetylene is, however, considerably higher, being about 1436° F.

In the smaller percentage which is necessary to form an explosive mixture, and in the lower temperature of ignition, acetylene is somewhat more dangerous in case of leakage than coal-gas; while, on the other hand, the very small size of the burner for the former gas allows it to escape much more slowly in the event of the flame being blown out or the burner being accidentally left turned on.

Illuminating power. The illuminating power of acetylene as compared with coal-gas varies with the type of burner employed. In a suitable burner 5 cubic feet of acetylene per hour will give 240 candle-power, while the same quantity of coal-gas gives 16 candle-power. Acetylene is, however, generally burnt in much smaller burners, consuming from ½ to 1 cubic foot per hour. Under these conditions the illuminating power of acetylene is from six times to ten times as great as that of coal-gas.

Generators. It would be impossible, within the limits of this chapter, to give a detailed description of the numerous forms of acetylene generator which have been devised. The fact that it is only necessary to bring water into contact with carbide of calcium in order to generate the gas makes the designing of a generator apparently so simple a matter that many inventors have been tempted to devote their energies to the subject. The matter is really not so simple as it seems, and it is upon the many important details of design that the success, and even the safety, of the apparatus depend.

In the report of the Committee on the Exhibition of Acetylene Generators at the Imperial Institute in

June 1898,* the various forms of apparatus are classified as follows:

(1) Those in which the gas is generated by water being allowed to drip, or flow in a small stream, on to the top of the carbide.
(2) Those in which water rises around the carbide.
(3) Those in which the carbide falls into water.

These are again subdivided into:

AUTOMATIC.

By automatic generators are meant those which have a storage capacity for gas less than the total volume which the charge of carbide is capable of generating, and which depend upon some special contrivance for stopping contact between the water and carbide.

NON-AUTOMATIC.

Non-automatic generators are those in which a holder of sufficient capacity is provided to receive the whole of the gas made from the largest charge of carbide which the apparatus is capable of taking.

This report gives a detailed description of the various forms of generator tested by the committee, together with much other useful information on the subject. Since it was written, many new forms of apparatus have been placed on the market, all of which, however, fall within the above-mentioned classification.

Soon after the introduction of carbide of calcium as an article of commerce into this country, it became evident that unless this substance were placed under some restrictions, serious accidents might arise. Notwithstanding the great difference between carbide and petroleum, it was recognised that the danger attending the storage of the two substances is much the same, since it arises from the liability of both to create an explosive atmosphere by giving off inflammable gas or vapour. Legislation.

* This report was issued by the Society of Arts, and may be obtained from William Trounce, 10 Gough Square, Fleet Street, London.

Consequently it was decided that the best method of dealing with the danger was to take advantage of the power provided in Section 14 of the Petroleum Act, 1871, of bringing other substances within the scope of that Act, and to subject carbide of calcium to such of the provisions of the Petroleum Acts as were applicable.

An Order in Council to this effect was accordingly made on February 26, 1897. This Order will be found in Appendix XII. together with a subsequent Order in Council dated July 7, 1897, by which a quantity up to 5 lbs., when kept in hermetically closed metal vessels containing not more than 1 lb., is exempted from the necessity of licence.

It is not therefore lawful for any person to keep more than 5 lbs. of carbide of calcium, whether for sale or for use without a licence from the local authority under the Petroleum Acts. The conditions to be attached to such licence rest entirely with the local authority, and will vary somewhat in different places; but it is usual to attach such conditions as will afford protection not only in the storage, but also in the use of carbide on the licensed premises. The power to attach conditions in regard to the construction and position of the generator in which the carbide is to be used has not, as far as the authors are aware, ever been questioned; and though there may be some doubt on the matter, it is probable that a Court of Law would hold that such conditions come within the wording of Section 9 of the Petroleum Act, 1871. Certainly these conditions do come within the wording of that section if it is held, as it very well may be, that carbide, even when in the generator, is being "kept" on the premises until the whole of it has been decomposed in the formation of acetylene gas.

Licences.

In preparing licences for carbide of calcium, local authorities will probably be guided in some measure

by the forms adopted by the London County Council, who have had the advantage of the assistance of the Home Office and of competent scientific advisers in framing their regulations.

The forms of licence adopted by this body, together with a memorandum issued by them, will be found in Appendix VI.

Precautions. In dealing with the dangers which have to be guarded against in keeping carbide of calcium, it should be clearly understood that the material by itself is wholly inexplosive and incombustible, and is absolutely safe so long as no water or moisture can reach it.

The carbide should be kept, therefore, in hermetically sealed metal vessels, which should be protected from the weather and stored in a dry place. As some gas may be formed from contact with the moisture of the atmosphere whenever the carbide vessels are opened or are not perfectly air-tight, it is desirable that the place of storage should be thoroughly ventilated, and that precautions should be taken to prevent the ignition of any gas which may be so formed. Thus a naked light * should never be brought into close proximity to an open vessel containing, or which has contained, carbide, nor should such light be used in any building where large quantities of carbide are stored.

Another danger may arise in the case of a fire from some other cause, which may damage the carbide vessels. In attempting to extinguish the fire, water may then come in contact with the carbide, giving rise to a copious evolution of gas, which will add to the conflagration, even if it does not cause a disastrous explosion. For this reason no large amount of carbide should be allowed to be stored in a shop or dwelling-house, or in any highly inflammable building; and when a fire does occur in a large carbide store, the Fire Brigade should

* See remarks on Safety Lamps (p. 159).

be warned not to attempt to extinguish it in the usual manner.

Quantity. It has been usual in licences to require that carbide should be kept in vessels containing not more than 112 lbs., but owing to the smaller size to which the material is now broken, the vessels originally designed to hold a hundredweight will now contain 140 lbs., and there is no special objection to the larger amount being allowed.

With regard to the quantity to be kept on any one premises, it must be remembered that in the case of large stores the danger is measured, not by the quantity of carbide, but by the amount of water which can gain access to it at any one time. Consequently it is not usual to limit the amount of carbide which may be kept in a large store. In the special cases where licences are granted for the keeping of carbide in a shop or dwelling-house, the quantity should be strictly limited. As some guide in fixing the limit, it should be remembered that as one pound of carbide will produce 5 cubic feet of gas, and as an atmosphere of acetylene and air commences to be explosive when the proportion of the former reaches 3 per cent., therefore 3 lbs. of carbide, if all converted into gas at once, would render a space of 500 cubic feet explosive.

It would be necessary, however, in order to convert the whole of the carbide into gas, that there should be nearly an equal weight of water in contact with the material. Where the evolution of gas is rapid, an explosive atmosphere may form in a portion of the space with a less quantity of gas than would be necessary to render the whole space capable of explosion.

Safety of generator. As already stated, it is usual where carbide of calcium is required for use on the premises to attach to the licence conditions in regard to the situation, construction, and method of employment of the generator.

The apparatus should always be placed in a well-ventilated outbuilding or in the open air, and never in a shop or dwelling-house. No artificial light capable of igniting gas should ever be taken into, or near, the building in which the generator is erected. Strict rules should be enjoined to prevent the access of children or unauthorised persons to the generator or to the store of carbide, and no person should be given charge of the apparatus without being thoroughly instructed in its use. If the generator is fitted with a blow-off pipe, this should be carried up through the roof of the building, so as to discharge into the open air.

Residue.

As the residue from the generator is not always wholly expended, it is necessary that it should be immersed in at least ten times its bulk of water before being thrown into the drains, as otherwise dangerous accumulations of gas may take place in the sewers.

In regard to the construction of generators, local authorities, unless they have some competent expert adviser, will usually have considerable difficulty in laying down regulations, or in approving any particular generator which it is proposed to erect on the premises of an applicant for a licence for carbide.

As this has been a difficulty much felt throughout the country, a committee of experts was requested to consider the question, and to carry out tests of such generators as might be brought before them. It is anticipated that their report will be of the greatest value to local authorities in determining the safety or otherwise of any particular generator. This report is not yet issued.

Purity of carbide.

Another condition which it is usual to insert in licences is that no carbide should be kept which is not commercially pure. It was thought that if impurities were present in such amount as to develop

large percentages of phosphoretted or siliciuretted hydrogen, there would be a danger of spontaneous ignition of the acetylene generated. Experiments made by Professor Lewes, conjointly with one of the authors, have, however, shown that the percentage of these gases necessary to produce spontaneous ignition is so great that carbide which is dangerous from this cause would be altogether unfit for practical use. There would be little chance, therefore, of finding in the market carbide of such a dangerous degree of impurity.

Harbour By-laws. The power of harbour authorities to make by-laws for petroleum spirit applies equally to carbide of calcium. It is preferable that the by-laws made for the latter should be entirely distinct from those made for petroleum. To assist harbour authorities a Model Code has been prepared (see Appendix XIII.), which contains all the provisions necessary for ensuring public safety; but this code is, of course, in no way binding.

Compressed acetylene. It has already been stated that acetylene when compressed is possessed of explosive properties by itself, that is, without the admixture of air. On the Continent more than one serious accident has occurred from the use of the compressed gas, and as it seemed likely that proposals would be made to use acetylene in this form in the United Kingdom, it was considered advisable to deal with the matter at the outset.

Accordingly, after certain experiments had been made to confirm those of Continental chemists, it was decided to prohibit the compression of acetylene except when it can be shown that in admixture with any substance, or in any form or condition, it is free from explosive properties when compressed. This was done by an Order in Council, dated November 26, 1897, under the Explosives Act (see Appendix XIV.), which

declares that, with the above exception, acetylene when liquid, or when compressed to a pressure exceeding the equivalent of 100 inches of water, shall be deemed to be an explosive under that Act, and shall be prohibited from being manufactured, imported, kept, conveyed or sold.

Exemptions. Advantage has been taken of the exception, and it has been demonstrated by experiment to the satisfaction of the Secretary of State that a mixture of twenty parts of acetylene to eighty parts of oil-gas compressed to a pressure of 150 lbs. to the square inch, is free from explosive properties. An Order of Secretary of State, dated March 28, 1898, was accordingly made exempting this mixture from being deemed to be an explosive, and consequently from prohibition. (See Appendix XIV.)

Successful experiments have also been carried out in the presence of one of the authors to show that acetylene, when compressed into porous material, both with and without acetone, is free from danger of explosion under ordinary conditions. An Order of Secretary of State has accordingly been made exempting the gas when compressed under these conditions from being deemed to be an explosive. (See Appendix XIV.)

The capacity of the liquid, acetone, for absorbing acetylene is very remarkable. At a pressure of ten atmospheres one volume of acetone will absorb about 250 volumes of acetylene.

Acetylene mixed with air. A similar Order in Council under the Explosives Act dated May 15, 1900, has been made, prohibiting the use of acetylene in admixture with air. (See Appendix XIV.) It was proposed to obtain a better combustion of the gas by mixing it with a certain proportion of air in the pipes, and one installation on this principle was erected in this country. This proposal has been

experimented with in America and resulted in several accidents. It was in order to prevent a repetition of such accidents in this country that the prohibition has been issued. When it is remembered that the most powerfully explosive mixture of acetylene and air is formed when the proportion of the former is 50 per cent., and that even when 80 per cent. is present the mixture can be exploded, it will be seen that no addition of air which would be of value in assisting combustion can be safely employed.

The Order in Council expressly states that the prohibition does not extend to a mixture of gas and air formed in the burner or contrivance for consuming the gas, as, for instance, in a Bunsen burner, or in a gas engine; nor to a mixture which occurs in a well-designed generator when first used or re-charged; and therefore prosecutions under the Order should only be instituted in cases where mixtures of gas and air are deliberately made throughout an acetylene installation, or where a generator is so badly designed as to allow such a mixture to be formed to a dangerous extent.

Accidents.

Owing probably to the restraining influence of legislation on the subject, accidents with acetylene in this country have not been numerous, though the gas is now being used to a large and rapidly increasing extent. Those accidents which have occurred have all been due to culpable carelessness in connection with generators. In nearly every case it is believed that the cause was the bringing of a naked light in close proximity to a generator under examination or repair.

Other uses of carbide and acetylene.

At present the use of carbide of calcium in the United Kingdom is confined entirely to the production of acetylene for illuminating purposes, but other applications likely to become of importance have been initiated in Germany. These are as follows:—

The production of metals from their ores. By mixture with carbide and subsequent exposure to gentle heat, the ores of copper and lead can be readily reduced, but whether the method is an economical one or not can only be shown by experience.

Carbide can also be used for the production of steel and for the surface hardening of armour plates. Lamp-black is now being manufactured from acetylene in Germany with considerable success, the product being of exceedingly good quality.

It is probable also that the use of acetylene for gas-engines will obtain considerable importance, while the facility with which the gas can be converted into various organic substances may lead to important industries in the synthetical production of such substances on a commercial scale.

For further information on the subject of carbide of calcium and acetylene, the reader should refer to Professor Vivian Lewes' *Acetylene.*

APPENDIX I.

IMPORTS OF PETROLEUM INTO THE UNITED KINGDOM DURING THE YEAR ENDED DECEMBER 31, 1900.

(Stated in Barrels of 41 gallons each.)

AMERICAN.

Port.	Ordinary Kerosene.	Water-White Kerosene.	Total Kerosene.	Gas Oil.
London . .	795,690	206,810	1,002,500	164,340
Liverpool . .	274,580	71,870	346,450	86,130
Manchester . .	104,880	100	104,980	72,260
Avonmouth . .	316,270	20,100	336,370	42,150
Hull . . .	232,980	26,000	258,980	—
South Shields .	97,800	12,620	110,420	—
Sunderland . .	50,750	—	50,750	—
Cardiff . . .	23,020	—	23,020	—
Plymouth . .	92,880	2,160	95,040	26,320
Southampton .	22,010	—	22,010	—
Swansea . .	—	—	—	6,550
Dublin . . .	164,750	5,290	170,040	—
Belfast . . .	97,340	6,950	104,290	—
	2,272,950	351,900	2,624,850	397,750

RUSSIAN.

Port.	Ordinary Kerosene.	High Test Kerosene.	Total Kerosene.	Solar Oil Distillate.
London . . .	492,290	106,560	598,850	355,810
Liverpool . .	73,620	—	73,620	22,800
Manchester . .	306,380	77,420	383,800	57,230
Hull . . .	32,510	—	32,510	—
South Shields .	55,160	—	55,160	—
Cardiff . . .	71,530	—	71,530	—
Barrow . . .	17,000	—	17,000	—
Southampton .	6,110	—	6,110	—
Dublin . . .	11,250	—	11,250	40,520
Belfast . . .	94,730	—	94,730	37,320
	1,160,580	183,980	1,344,560	513,680

IMPORTS OF PETROLEUM INTO THE UNITED KINGDOM DURING THE YEAR ENDED DECEMBER 31, 1899.

(Stated in Barrels of 41 gallons each.)

AMERICAN.

Port.	Ordinary Kerosene.	Water-White Kerosene.	Total Kerosene.	Gas Oil.
London . . .	863,260	211,460	1,074,720	180,970
Liverpool . .	285,620	62,150	347,770	62,280
Manchester . .	90,360	—	90,360	65,160
Avonmouth . .	308,330	18,040	326,370	16,560
Hull . . .	247,730	29,060	276,790	—
South Shields .	120,720	14,520	135,240	—
Sunderland . .	75,580	—	65,580	—
Cardiff . . .	22,790	—	22,790	—
Plymouth . .	66,140	3,070	69,210	26,380
Southampton . .	45,560	—	45 560	—
Barrow . . .	50,370	—	50,370	9,120
Dublin . . .	143,670	2,950	146,620	—
Belfast . . .	76,710	11,220	87,930	43,020
Waterford . .	3,870	80	3,950	—
	2,390,710	352,550	2,743,260	403,490

RUSSIAN.

Port.	Ordinary Kerosene.	High Test Kerosene.	Total Kerosene.	Solar Oil Distillate.
London . . .	471,510	126,240	597,750	127,660
Liverpool . . .	89,520	7,380	96,900	—
Manchester . .	266,830	102,830	369,660	57,610
Hull . . .	16,080	—	16,080	—
South Shields . .	37,650	—	37,650	—
Cardiff . . .	34,150	—	34,150	—
Barrow . . .	6,200	—	6,200	—
Belfast . . .	76,120	—	76,120	13,940
Swansea . . .	—	—	—	5,640
	998,060	236,450	1,234,510	204,850

IMPORTS OF PETROLEUM SPIRIT IN BARRELS INTO THE UNITED KINGDOM DURING THE YEAR 1900.

Description.	Ports.				
	London.	Liverpool.	Bristol.	Dublin.	
	Barrels.	Barrels.	Barrels.	Barrels.	Total Barrels.
Ordinary and deodorised spirit	35,807	52,500	8,050	698	97,055
76° Gasoline (Sp. Gr. ·680) .	15,625	2,000	600	—	18,225
Benzine . . .	2,750	6,100	700	—	9,550
Motor-car spirit .	2,000	1,750	—	—	3,750
Stove spirit . .	50	100	—	—	150
	56,232	62,450	9,350	698	128,730

IMPORTS IN CASES.
(Each case containing two 4-gallon tins).

	London.	Liverpool.	Bristol.	
	Cases.	Cases.	Cases.	Total Cases.
Gasoline . . .	2,000	5,000	2,250	9,250

IMPORTS OF PETROLEUM SPIRIT IN BARRELS INTO THE UNITED KINGDOM DURING THE YEAR 1899.

Description.	Ports.				
	London.	Liverpool.	Bristol.	Hull.	
	Barrels.	Barrels.	Barrels.	Barrels.	Total Barrels.
Ordinary and deodorised spirit	42,538	34,095	14,388	4,424	95,445
76° Gasoline (Sp. Gr. ·680)	21,084	4,350	1,650	700	27,784
Benzine . .	1,600	7,500	1,350	—	10,450
Motor-car spirit .	250	—	—	—	250
	65,472	45,945	17,388	5,124	133,929

IMPORTS IN CASES.
(Each case containing two 4-gallon tins.)

	London.	Liverpool.	Bristol.	Hull.	
	Cases.	Cases.	Cases.	Cases.	Total Cases.
Gasoline . .	4,000	8,000	2,250	100	14,350

APPENDIX II.

PETROLEUM ACT, 1871, AS AMENDED.

An Act for the safe keeping of Petroleum and other substances of a like nature. [August 21, 1871.]

Remarks.

1. This Act may be cited as "The Petroleum Act, 1871."

Sect. 1, 1871. Short title of Act.

2. In this Act, if not inconsistent with the context, the following terms have the meanings hereinafter assigned to them; (that is to say),

Sect. 2, 1871. Interpretation of certain terms in the Act.

The term "borough" means—

In England any place for the time being subject to the provisions of the Municipal Corporation Act, 1882, and the Acts amending the same:

In Scotland any royal burgh and any burgh or town returning or contributing to return a member or members to serve in Parliament;

In Ireland any place for the time being subject to the provisions of the Act of the session of the third and fourth years of the reign of Queen Victoria, chapter one hundred and eight, "for the regulation of municipal corporations in Ireland, and the Acts amending the same:"

The term "person" includes a body corporate;

The term "Secretary of State" means one of His Majesty's Principal Secretaries of State:

The term "harbour" means any

Remarks.

harbour properly so called, whether natural or artificial, and any port, haven, estuary, tidal river or other river, canal or inland navigation navigated by sea-going ships, and any dock, pier, jetty, or other works in or at which ships do or can ship or unship goods or passengers:

The term "harbour authority" includes any persons or person being or claiming to be proprietors or proprietor of or intrusted with the duty or invested with the power of improving, maintaining, or managing any harbour:

The term "ship" includes every description of vessel used in navigation, whether propelled by oars or otherwise:

The term "Court of Summary Jurisdiction" means and includes any justice or justices of the peace, sheriff or sheriff substitute, metropolitan police magistrate, stipendiary or other magistrate, or officer, by whatever name called, to whom jurisdiction is given by the Summary Jurisdiction Acts or any Acts therein referred to, or to proceedings before whom the provisions of the Summary Jurisdiction Acts are or may be made applicable:

The term "county rate" means as regards Scotland the county general assessment leviable in pursuance of "The County General Assessment (Scotland) Act, 1868," and as regards Ireland the grand jury cess.

3. For the purposes of this Act the term "petroleum" includes any rock oil, Rangoon oil, Burmah oil, oil made from petroleum, coal, schist, shale, peat, or other bituminous substance, and any products of petroleum, or any

Sect. 3, 1871. It will be seen that the general definition of "petroleum" includes not only the whole class of mineral oils (see chap. i.), but also "any

of the above-mentioned oils; and the term "petroleum to which this Act applies," means such of the petroleum so defined as, when tested in manner set forth in Schedule One to this Act, gives off an imflammable vapour at a temperature of less than seventy-three degrees of Fahrenheit's thermometer.

A model of the apparatus for testing petroleum, as described in Schedule One to this Act, shall be deposited

Remarks.

products of petroleum." The definition would therefore include such solid substances as paraffin wax, and might even be held to cover other solid or liquid substances which are produced less directly from petroleum, coal-tar, &c., and which may not even be inflammable.

The definition is however narrowed down by the provision that the Act shall only apply to such of these substances as have a flash-point below 73° Fahr. (see chap. v.) The prescribed method of determining the flash-point will be found in the Schedule below.

It has been decided by the King's Bench in the case of London County Council *v.* Holtzapfels Compositions Company, Limited, that the Act applies not only to petroleum by itself, but also to mixtures of petroleum with other substances, whenever such mixtures have a flash-point below 73° Fahr. India-rubber solution and certain quick-drying paints made with petroleum spirit, come therefore within the operation of the Act.

Sect. 3, 1879. This Section provides for the verification of the testing in-

with the Board of Trade, and the Board of Trade shall, on payment of such fee, not exceeding five shillings, as they from time to time prescribe, cause to be compared with such model and verified every apparatus constructed in accordance with Schedule One to this Act which is submitted to them for the purpose, and if the same is found correct shall stamp the same with a mark approved of by the Board and notified in the London Gazette.

An apparatus for testing petroleum purporting to be stamped with the said mark shall, until the contrary is proved, be deemed to have been verified by the Board of Trade.

All fees under this section shall be paid into the Exchequer.

4. Every harbour authority shall frame and submit for confirmation to the Board of Trade by-laws for regulating the place or places at which ships carrying petroleum to which this Act applies are to be moored in the harbour over which such authority has jurisdiction, and are to land their cargo, and for regulating the time and mode of, and the precautions to be taken on, such landing. The harbour authority shall publish the by-laws so framed with a notice of the intention of such authority to apply for the confirmation thereof. The Board of Trade may confirm such by-laws with or without any omission, addition, or alteration, or may disallow the same.

Every such by-law when confirmed shall be published by the harbour authority, and may be from time to time altered or repealed by a by-law made in like manner. By-laws under

Remarks.

strument. Regulations for such verification, issued by the Standards Department of the Board of Trade, will be found in Appendix VII.

Sect. 4, 1871. Harbour authorities may, with the sanction of the Board of Trade, make by-laws under this Section regulating the following matters:

(1) Places where ships carrying petroleum spirit are to be moored.

(2) Places where such ships are to land their cargo.

(3) Time and mode of such landing.

(4) Precautions to be taken in such landing.

It will be seen that there is no power to make by-laws prohibiting the bringing of petroleum into the harbour; nor is there power to regulate the shipping of petroleum, though this is

this section shall be published in such manner as the Board of Trade may from time to time direct.

If at any time it appears to the Board of Trade that there is no by-law for the time being in force under this section in any harbour the Board of Trade may, by notice, require the harbour authority of such harbour to frame and submit to them a by-law for the purposes of this section, and if such harbour authority make default in framing a by-law and obtaining the confirmation thereof within the time limited by such notice the Board of Trade may make a by-law for the purposes of this section, and such by-law shall have the same effect as if it had been framed by the harbour authority and confirmed by the Board of Trade.

Where any ship or cargo is moored, landed, or otherwise dealt with in contravention of any by-law for the time being in force under this Act in any harbour, the owner and master of such ship, or the owner of such cargo, as the case may be, shall each incur a penalty not exceeding fifty pounds for each day during which such contravention continues, and it shall be lawful for the harbour-master or any other person acting under the orders of the harbour authority of such harbour to cause such ship or cargo to be removed, at the expense of the owner thereof, to such place as may be in conformity with the said by-law, and all expenses incurred in such removal may be recovered in the same manner in which penalties are by this Act made recoverable.

5. The owner or master of every

Remarks.

regulated to some extent by laying down the place where ships carrying petroleum are to be moored.

It is desirable that separate by-laws should be made for carbide of calcium.

In Appendix V. will be found a Model Code of harbour by-laws for petroleum, and in Appendix XIII. a similar code for carbide of calcium. These Model Codes have been prepared by the Home Office for the assistance of harbour authorities, but they are in no way binding, and are subject to any modifications or additions which may be rendered necessary by local requirements.

Sect 5, 1871. It should

ship carrying a cargo any part of which consists of petroleum to which this Act applies, on entering any harbour within the United Kingdom, shall give notice of such cargo to the harbour authority having jurisdiction over such harbour.

If such notice is not given the owner and master of such ship shall each incur a penalty not exceeding the sum of five hundred pounds, unless it is shown to the satisfaction of the court before which the case is tried that neither the owner nor the master knew the nature of the goods to which the proceedings relate, nor could with reasonable diligence have obtained such knowledge.

6. Where any petroleum to which this Act applies—

(*a*) Is kept at any place except during the seven days next after it has been imported; or,

(*b*) Is sent or conveyed by land or water between any two places in the United Kingdom; or,

(*c*) Is sold or exposed for sale;

the vessel containing such petroleum shall have attached thereto a label in conspicuous characters, stating the description of the petroleum, with the addition of the words "highly inflammable," and with the addition—

(*a*) In the case of a vessel kept, of the name and address of the consignee or owner:

(*b*) In the case of a vessel sent or conveyed, of the name and address of the sender:

(*c*) In the case of a vessel sold or exposed for sale, of the name and address of the vendor.

All petroleum to which this Act

Remarks.

be noted that in cases where petroleum or carbide of calcium is shipped on a vessel without the knowledge of the owner or master, the exemption from penalty can only be claimed if it is shown that such knowledge could not, with reasonable diligence, have been obtained.

Sect 6, 1871. In the case of carbide of calcium the following marking is substituted:

"CARBIDE of CALCIUM. DANGEROUS if not kept DRY." "The contents of this package are liable if brought into contact with moisture to give off a highly inflammable gas."

The requirements as to the package bearing the name and address of the owner, sender, or vendor, are the same as for petroleum.

applies which is kept, sent, conveyed, sold, or exposed for sale, in contravention of this section, shall, together with the vessel containing the same, be forfeited, and in addition thereto the person keeping, sending, selling, or exposing for sale the same shall for each offence be liable to a penalty not exceeding five pounds.

7. Save as hereinafter mentioned, after the passing of this Act, petroleum to which this Act applies shall not be kept, except in pursuance of a licence given by such local authority as is in this Act mentioned.

All petroleum kept in contravention of this section shall, together with the vessel containing the same, be forfeited, and in addition thereto the occupier of the place in which such petroleum is so kept shall be liable to a penalty not exceeding twenty pounds a day for each day during which such petroleum is so kept.

This section shall not apply to any petroleum kept either for private use or for sale, provided the following conditions are complied with:

(1) That it is kept in separate glass, earthenware, or metal vessels, each of which contains not more than a pint, and is securely stopped:

(2) That the aggregate amount kept, supposing the whole contents of the vessels to be in bulk, does not exceed three gallons.

8. The following bodies shall respectively be the local authority to grant licences under this Act in the districts hereinafter mentioned; (that is to say),

(1) In the City of London, except as

Remarks.

Sect. 7, 1871. This section applies to keeping for private use or for manufacture, as well as for sale; but persons keeping petroleum spirit for use in motor-cars are exempted from the necessity of licence, so long as they conform to the Regulations which will be found in Appendix IX.

A licence is not required for a carriage in which petroleum is hawked. (See Petroleum Act, 1881, below.)

Sect. 8, 1871. By the Local Government Acts, the local authorities for petroleum have been altered as regards England and Wales.

hereafter in this section mentioned, the Court of the Lord Mayor and aldermen of the said city:

(2) In the County of London, except the City of London, and except as hereafter in this section mentioned, the County Council of London.

(3) In any borough in England or Ireland, except as hereafter in this section mentioned, the mayor, aldermen, and burgesses acting by the council:

(4) (Repealed)

(5) (Repealed)

(6) In any borough in Scotland, except as hereafter in this section mentioned, the town council:

(7) In any place in Scotland, except as hereafter in this section mentioned, within the jurisdiction of police commissioners or trustees exercising the functions of police commissioners under any general or local Act, and not being a borough or comprising any part of a borough, the police commissioners or trustees:

(8) In any harbour within the jurisdiction of a harbour authority, whether situate or not within the jurisdiction of any local authority before in this section mentioned, the harbour authority, to the exclusion of any other local authority:

(9) In any place in which there is no local authority as before in this section defined, in England the District Council, in Ireland the justices in petty sessions assembled, and in Scotland any two or more justices of the peace for the county sitting as judges in the justice of peace court.

Remarks.

They may now be summarised as follows:

In the City of London or any borough—the Corporation.

In the County of London—the London County Council.

In any harbour — the Harbour Authority.

In any other place—the District Council.

The local authority in Scotland and Ireland remains as in the Act.

9. Licences in pursuance of this Act shall be valid if signed by two or more

Sect. 9, 1871. The conditions which may be at-

of the persons constituting the local authority, or executed in any other way in which other licences, if any, granted by such authority are executed. Licences may be granted for a limited time and may be subject to renewal or not in such manner as the local authority think necessary.

There may be annexed to any such licence such conditions as to the mode of storage, the nature and situation of the premises in which, and the nature of the goods with which petroleum to which this Act applies is to be stored, the facilities for the testing of such petroleum from time to time, the mode of carrying such petroleum within the district of the licensing authority, and generally as to the safe keeping of such petroleum as may seem expedient to the local authority.

Any licensee violating any of the conditions of his licence shall be deemed to be an unlicensed person. There may be charged in respect of each licence granted in pursuance of this Act such sum, not exceeding five shillings, as the local authority may think fit to charge.

Remarks.

tached to a licence are as to:

(1) Mode of storage.

(2) Nature and situation of the premises.

(3) Nature of the goods with which the petroleum may be stored.

(4) Facilities for testing.

(5) Mode of carrying petroleum within the district of the licensing authority.

(6) General safe keeping of the petroleum.

These powers are much wider than in the case of harbour by-laws, and would cover almost any condition which the local authority may consider necessary for safety.

Forms of licence as used by the London County Council will be found in Appendix VI.

Before a licence is granted, the officer of the local authority should inspect the premises, and ascertain whether the place is suitable. For the precautions to be taken generally, and for remarks as to the suitability of places for keeping petroleum, see chap. ix.

In the case of petroleum or carbide of calcium for private use or for manufacturing purposes, a term should be added to the licence to the effect that

10. If on any application for a licence under this Act the local authority refuse the licence, or grant the same only on conditions with which the applicant is dissatisfied, the local authority shall, if required by the applicant, deliver to him in writing under the hand or hands of one or more of the persons constituting the local authority, a certificate of the grounds on which they refused the licence or annexed conditions to the grant thereof.

The applicant within ten days from the time of the delivery of the certificate may transmit the same to a Secretary of State if the application is for a licence in England, *to the Secretary for Scotland if the application is for a licence in* Scotland, and to the Lord-Lieutenant if the application is for a licence in Ireland, together with a memorial, praying that notwithstanding such refusal the licence may be granted, or that the conditions may not be imposed, or may be altered or modified in such manner and to such extent as may be set forth in such memorial.

It shall be lawful for the Secretary of State, *the Secretary for Scotland*, or the Lord-Lieutenant, if he think fit, on consideration of such memorial and certificate, and, if he think it necessary or desirable, after due inquiry and a report by such person as he may appoint for that purpose, to grant the licence prayed for, either absolutely or with such conditions as he thinks fit, or to alter or modify the conditions imposed by the local authority; and the licence

Remarks.

the officer of the local authority must be given free access to the premises.

Sect. 10, 1871. This section provides for appeal in the case of a licence being refused by the local authority, or of the applicant being dissatisfied with the conditions imposed. In England the appeal must be made to the Home Secretary; in Ireland to the Lord-Lieutenant; and in Scotland to the Secretary for Scotland. (Secretary for Scotland Acts.)

Any person making an appeal should first obtain the certificate required by the first paragraph of the section.

Remarks.

so granted, or altered and modified, as the case may be, when certified under the hand of a Secretary of State, *the Secretary for Scotland*, or the Lord-Lieutenant, shall be to all intents as valid as if granted by the local authority.

11. Any officer authorised by the local authority may purchase any petroleum from any dealer in it, or may, on producing a copy of his appointment, purporting to be certified by the clerk or some member of the local authority, or producing some other sufficient authority, require the dealer to show him every or any place, and all or any of the vessels in which any petroleum in his possession is kept, and to give him samples of such petroleum on payment of the value of such samples.

When the officer has by either of the means aforesaid taken samples of petroleum, he may declare in writing to the dealer that he is about to test the same, or cause the same to be tested, in manner set forth in Schedule One to this Act, and it shall be lawful for him to test the same or cause the same to be tested, at any convenient place at such reasonable time as he may appoint, and the dealer or any person appointed by him may be present at the testing, and if it appear to the officer or other person so testing that the petroleum from which such samples have been taken is petroleum to which this Act applies, such officer or other person may certify such fact, and the certificate so given shall be receivable as evidence in any proceedings that may be taken against a dealer in petroleum in pursuance of this Act; but it shall be lawful

Sect. 11, 1871. This section gives a right of purchasing samples, and of inspection of any premises on which petroleum, whether spirit or oil, is kept for sale; but does not give a right of entry into a place where petroleum is kept for private use or for purposes of manufacture.

The officer appointed by the local authority can only claim a right of entry into private premises or factories where he believes that petroleum spirit is kept, under a warrant as provided by Section 13, unless the place is licensed, and there is a term in the licence requiring the occupier to allow him free access.

Remarks.

for a dealer proceeded against to give evidence in proof that such certificate is incorrect, and thereupon the court before which any such proceedings may be taken may, if such court think fit, appoint some person skilled in testing petroleum to examine the samples to which such certificate relates, and to declare whether such certificate is correct or incorrect.

Any expenses incurred in testing any petroleum of such dealer in pursuance of this section shall, if such dealer be convicted of keeping, sending, conveying, selling, or exposing for sale, petroleum in contravention of this Act, be deemed to be a portion of the costs of the proceedings against him, and shall be paid by him accordingly. In any other event such expenses shall be paid by the local authority out of any funds for the time being in their hands, and in case the local authority are the justices, out of the county rate.

12. Any dealer who refuses to show to any officer authorised by the local authority every or any place or all or any of the vessels in which petroleum in his possession is kept, or to give him such assistance as he may require for examining the same, or to give to such officer samples of such petroleum on payment of the value of such samples, or who wilfully obstructs the local authority, or any officer of the local authority, in the execution of this Act, shall incur a penalty not exceeding twenty pounds.

Sect. 12, 1871. This section only applies to dealers, *i.e.*, persons who keep petroleum for sale. (See remarks on preceding section.)

13. Where any court of summary jurisdiction is satisfied by information on oath that there is reasonable ground to believe that any petroleum to which

Sect. 13, 1871. This section provides for entry and search for petroleum kept otherwise than for

this Act applies is being kept, sent, conveyed, or exposed for sale within the jurisdiction of such court in contravention of this Act, at any place, whether a building or not, or in any ship or vehicle, such court shall grant a warrant by virtue whereof it shall be lawful for any person named in such warrant to enter the place, ship, or vehicle named in such warrant, and every part thereof, and examine the same and search for petroleum therein, and take samples of any petroleum found therein, and if any petroleum to which this Act applies be found therein, which is kept, sent, conveyed, or exposed for sale, in contravention of this Act, to seize and remove such petroleum, and the vessel containing the same, and to detain such petroleum and vessel until some court of summary jurisdiction has determined whether the same are or are not forfeited, the proceedings for which forfeiture shall be commenced forthwith after the seizure.

Any person seizing any petroleum to which this Act applies in pursuance of this section shall not be liable to any suit for detaining the same, or for any loss or damage incurred in respect of such petroleum, otherwise than by any wilful act or neglect while the same is so detained.

If any petroleum to which this Act applies is seized in pursuance of this section in any ship or vehicle, the person seizing the same may use for the purposes of the removal thereof, during twenty-four hours after the seizure, the said ship or vehicle, with the tackle, beasts, and accoutrements belonging thereto, and if he do so shall pay to the owner

Remarks.

sale. (See remarks on Section 11.)

Remarks.

thereof a reasonable recompense for the use thereof, and the amount of such recompense shall, in case of dispute, be settled by the court of summary jurisdiction before whom proceedings for the forfeiture are taken, and may be recovered in like manner as penalties under this Act may be recovered.

Any person who, by himself or by any one in his employ or acting by his direction or with his consent, refuses or fails to admit into any place occupied by or under the control of such person, any person demanding to enter in pursuance of this section, or in any way obstructs or prevents any person in or from making any such search, examination, or seizure, or taking any such samples as authorised by this section, shall be liable to pay a penalty not exceeding twenty pounds, and to forfeit all petroleum to which this Act applies which is found in his possession or under his control.

14. His Majesty may from time to time make, revoke, and vary Orders in Council directing this Act or any part thereof to apply to any substance, and this Act, or the part thereof specified in the Order shall, during the continuance of the Order, apply to such substance, and shall be construed and have effect as if throughout it such substance had been included in the definition of petroleum to which this Act applies, subject to the following qualifications:

Sect. 14, 1871. The only substance brought under the operation of the Act by this section is carbide of calcium. The Orders in Council will be found in Appendix XII.

(1) The quantity of any substance to which this Act is directed by Order in Council to apply, which may be kept without a licence, shall be such quantity only as is specified in that behalf in

Remarks.

such order, or if no such quantity is specified no quantity may be kept without a licence:

(2) The label on the vessel containing such substance shall be such as may be specified in that behalf in the order.

15. In England and Ireland all offences and penalties under this Act, and all money and costs directed by this Act to be recovered as penalties, may be prosecuted and recovered in manner provided by the Summary Jurisdiction Acts.

Sect. 15, 1871. This section deals with proceedings for offences and penalties.

In Scotland all offences and penalties under this Act, and all money and expenses by this Act directed to be recovered as penalties, shall, save as hereinafter provided, be prosecuted and recovered at the instance of the procurator fiscal or of any officer authorised in that behalf by the harbour authority or local authority under the provisions of the Summary Jurisdiction Acts before a court of summary jurisdiction, and all necessary powers and jurisdictions are hereby conferred on such court in Scotland.

Provided as follows:

(1) A court of summary jurisdiction shall not impose a penalty exceeding fifty pounds, but any such court may impose that or any less penalty for any one offence, notwithstanding the offence involves a penalty of higher amount.

(2) In Scotland any penalty exceeding fifty pounds shall be recovered and enforced in the same manner in which any penalty due to His Majesty under any Act of Parliament may be recovered and enforced.

(3) The "Court of Summary Jurisdiction," when hearing and determining

Remarks.

an information or complaint, shall be constituted in some one of the following manners; (that is to say),

(*a*) In England, either of two or more justices of the peace in petty sessions sitting at a place appointed for holding petty sessions, or of one of the magistrates hereinafter mentioned, sitting alone or with others at some court or other place appointed for the administration of justice; that is to say, the Lord Mayor, or any alderman of the City of London, a metropolitan police magistrate, a stipendiary magistrate, or some other officer or officers for the time being empowered by law to do alone or with others any act authorised to be done by more than one justice of the peace;

(*b*) In Scotland, of two or more justices of the peace sitting as judges in a justice of the peace court, or of one of the magistrates hereinafter mentioned sitting alone or with others at some court or other place appointed for the administration of justice; that is to say, the sheriff of the county or his substitute, or the provost or other magistrate of a royal burgh, or some other officer or officers for the time being empowered by law to do alone or with others any act authorised to be done by more than one justice of the peace:

(*c*) In Ireland, within the police district of Dublin Metropolis,

Remarks.

of one of the divisional justices of the police district of Dublin Metropolis, sitting at a police court within the said district; and elsewhere, of a stipendiary magistrate, sitting alone or with others, or of two or more justices of the peace in petty sessions, sitting at a place appointed for holding petty sessions.

(4) Repealed.

(5) Repealed.

(6) No conviction or order made in pursuance of this Act shall be quashed for want of form or be removed by certiorari or otherwise, either at the instance of the Crown or of any private party, into any superior court.

(7) Repealed.

(8) In Scotland all penalties imposed under the provisions of this Act by a Court of Summary Jurisdiction may be enforced in default of payment by imprisonment for a term not exceeding three calendar months; and all such penalties recovered and the proceeds of all forfeitures sold under this Act shall be paid to the clerk of the Court of Summary Jurisdiction, and by him accounted for and paid to the persons and for the purposes under stated; (that is to say),

(*a*) To the King's and Lord Treasurer's Remembrancer, on behalf of His Majesty, when the court is the sheriff's court:

(*b*) To the collector of county rates in aid of the general county assessment when the court is the justice of the peace court:

(*c*) To the treasurer of the burgh in aid of the funds of the burgh

Remarks.

when the court is a burgh court.

(9) In Ireland all penalties recovered under the provisions of this Act shall be applied according to the Fines, Ireland, Act, 1851, or any Act amending the same.

16. All powers given by this Act shall be deemed to be in addition to and not in derogation of any other powers conferred on any local or harbour authority by Act of Parliament, law, or custom, and every local authority and harbour authority may exercise such other powers in the same manner as if this Act had not passed; and nothing in this Act contained shall be deemed to exempt any person from any penalty to which he would otherwise be subject in respect of a nuisance.

Sect. 16, 1871. This section provides for the reservation of previous powers. It is not, however, desirable that harbour authorities should make by-laws for petroleum in virtue of powers which they may have under some other Act.

The Petroleum Act, 1871, shall continue in force until otherwise directed by Parliament.

Sect. 4, 1879. The Petroleum Act, 1871, was renewed annually until 1879, when it was made permanent.

SCHEDULE ONE.

Petroleum Act, 1879.

(42 & 43 Vict. c. 47.)

Mode of Testing Petroleum so as to ascertain the Temperature at which it will give off Inflammable Vapour.

Explanatory Remarks.
Fig. 1 [A]. Plate II.

The oil-cup consists of a cylindrical vessel 2″ diameter, $2\frac{2}{10}$″ height (internal), with outward projecting rim $\frac{5}{10}$″ wide, $\frac{3}{8}$″ from the top, and $1\frac{7}{8}$″ from the bottom of the cup. It is made of gun metal or brass (17 B.W.G.) tinned inside. A bracket, consisting of a short stout

Explanatory Remarks.

piece of wire bent upwards and terminating in a point, is fixed to the inside of the cup to serve as a gauge. The distance of the point from the bottom of the cup is $1\frac{1}{2}''$. The cup is provided with a close-fitting overlapping cover made of brass (22 B.W.G.), which carries the thermometer and test lamp. The latter is suspended from two supports from the side by means of trunnions upon which it may be made to oscillate; it is provided with a spout, the mouth of which is one-sixteenth of an inch in diameter. The socket which is to hold the thermometer is fixed at such an angle and its length is so adjusted that the bulb of the thermometer when inserted to its full depth shall be $1\frac{1}{2}''$ below the centre of the lid.

Figs. 1, 2, 3, 4.

The cover is provided with three square holes, one in the centre, $\frac{5}{10}''$ by $\frac{4}{10}''$, and two smaller ones, $\frac{3}{10}''$ by $\frac{2}{10}''$, close to the sides and opposite each other. These three holes may be closed and uncovered by means of a slide moving in grooves, and having perforations corresponding to those on the lid.

Fig. 2.

In moving the slide so as to uncover the holes, the oscillating lamp is caught by a pin fixed in the slide, and tilted in such a way as to bring the end of the spout just below the surface of the lid. Upon the slide being pushed back so as to cover the holes, the lamp returns to its original position.

Figs. 3, 4, 7.

Upon the cover, in front of and in line with the mouth of the lamp, is fixed a white bead,* the dimensions of which represent the size of the test flame to be used.

* (*i*) Figs. 1, 2, 3, 4.

Explanatory Remarks.

The bath or heated vessel consists of two flat-bottomed copper cylinders (24 B.W.G.), an inner one of 3″ diameter and $2\frac{1}{2}$″ height, and an outer one of $5\frac{1}{2}$″ diameter and $5\frac{3}{4}$″ height; they are soldered to a circular copper plate (20 B.W.G.) perforated in the centre, which forms the top of the bath, in such a manner as to enclose the space between the two cylinders, but leaving access to the inner cylinder. The top of the bath projects both outwards and inwards about $\frac{3}{8}$″; that is, its diameter is about $\frac{6}{8}$″ greater than that of the body of the bath, while the diameter of the circular opening in the centre is about the same amount less than that of the inner copper cylinder. To the inner projection of the top is fastened, by six small screws, a flat ring of ebonite, the screws being sunk below the surface of the ebonite, to avoid metallic contact between the bath and the oil cup. The exact distance between the sides and bottom of the bath and of the oil-cap is $\frac{1}{2}$″.* A split socket † similar to that on the cover of the oil-cup, but set at a right angle, allows a thermometer to be inserted into the space between the two cylinders. The bath is further provided with a funnel,‡ an overflow pipe,§ and two loop handles.‖

Fig. 1 [B].

Fig. 1 (*h*).

* This statement relates to the distance between the sides and bottom of the *cup* and the walls of the *inner cylinder*, which forms the air chamber.

† Fig. 1 (*e*) ‡ (*d*).
§ (*f*). ‖ (*gg*).

The bath rests upon a cast-iron tripod stand, to the ring of which is attached a copper cylinder or jacket* (24 B.W.G.) flanged at the top, and of such dimensions that the bath, while firmly resting on the iron ring, just touches with its projecting top the inward-turned flange. The diameter of this outer jacket is $6\frac{1}{2}$″. One of the

* Fig. 1 [C].

Explanatory Remarks

three legs of the stand serves as support for the spirit lamp attached to it by means of a small swing bracket.* The distance of the wick holder † from the bottom of the bath is 1″.*

* Fig. 1 (*a*).

† (*c*).

* The lamp is filled through the funnel *b*.

Two thermometers are provided with the apparatus, the one for ascertaining the temperature of the bath, the other for determining the flashing point. The thermometer for ascertaining the temperature of the water has a long bulb and a space at the top. Its range is from about 90° to 190° Fahrenheit. The scale (in degrees of Fahrenheit) is marked on an ivory back fastened to the tube in the usual way. It is fitted with a metal collar, fitting the socket, and the part of the tube below the scale should have a length of about 3½″ measured from the lower end of the scale to the end of the bulb. The thermometer for ascertaining the temperature of the oil is fitted with collar and ivory scale in a similar manner to the one described. It has a round bulb, a space at the top, and ranges from about 55° F. to 150° F.; it measures from end of ivory back to bulb 2¼″.

In both thermometers the capillary tube is widened at the top to prevent breakage through over-heating. The line on the scale of the long bulb thermometer indicating 130°, is rendered conspicuous by being drawn across the whole width of the ivory back. In a similar manner the line indicating 73° is specially marked on the round bulb thermometer.

Note.—A model apparatus is deposited at the Weights and Measures Department of the Board of Trade.

Directions for applying the Flashing Test.

(1) The test apparatus is to be placed for use in a position where it is not exposed to currents of air or draughts.

(2) The heating vessel or water bath is filled by pouring water into the

Explanatory Remarks.

funnel until it begins to flow out at the spout of the vessel. The temperature of the water at the commencement of the test is to be 130° Fahrenheit, and this is attained in the first instance either by mixing hot and cold water in the bath, or in a vessel from which the bath is filled, until the thermometer which is provided for testing the temperature of the water gives the proper indication; or by heating the water with the spirit lamp (which is attached to the stand of the apparatus) until the required temperature is indicated.

If the water has been heated too highly, it is easily reduced to 130° by pouring in cold water little by little (to replace a portion of the warm water) until the thermometer gives the proper reading.

When a test has been completed, this water bath is again raised to 130° by placing the lamp underneath, and the result is readily obtained while the petroleum cup is being emptied, cooled, and refilled with a fresh sample to be tested. The lamp is then turned on its swivel from under the apparatus, and the next test is proceeded with.

(3) The test lamp is prepared for use by fitting it with a piece of flat plaited candle wick, and filling it with colza or rape oil up to the lower edge of the opening of the spout or wick tube. The lamp is trimmed so that when lighted it gives a flame of about 0·15 of an inch diameter, and this size of flame, which is represented by the projecting white bead on the cover of the oil-cup, is readily maintained by

Explanatory Remarks.

simple manipulation from time to time with a small wire trimmer.

When gas is available it may be conveniently used in place of the little oil-lamp, and for this purpose a test-flame arrangement for use with gas may be substituted for the lamp.

(4) The bath having been raised to the proper temperature, the oil to be tested is introduced into the petroleum cup, being poured in slowly* until the level of the liquid just reaches the point of the gauge which is fixed in the cup. In warm weather the temperature of the room in which the samples to be tested have been kept should be observed in the first instance, and if it exceeds 65° the samples to be tested should be cooled down (to about 60°) by immersing the bottles containing them in cold water, or by any other convenient method. The lid of the cup, with the slide closed, is then put on, and the cup is placed into the bath or heating vessel. The thermometer in the lid of the cup has been adjusted so as to have its bulb just immersed in the liquid, and its position is not under any circumstances to be altered. When the cup has been placed in the proper position, the scale of the thermometer faces the operator.

* In pouring in the oil to be tested, great care should be taken not to splash it against the sides of the cup.

(5) The test lamp is then placed in position upon the lid of the cup, the lead line or pendulum, which has been fixed in a convenient position in front of the operator, is set in motion, and the rise of the thermometer in the petroleum cup is watched. When the temperature has reached about 66° the operation of testing is to be commenced, the test-flame being applied once for

every rise of one degree, in the following manner:—

The slide is slowly drawn open while the pendulum performs three oscillations, and is closed during the fourth oscillation.

NOTE.—If it is desired to employ the test apparatus to determine the flashing points of oils of very low volatility, the mode of proceeding is to be modified as follows:—

The air-chamber which surrounds the cup is filled with cold water to a depth of 1½ inches, and the heating vessel or water-bath is filled as usual, but also with cold water. The lamp is then placed under the apparatus and kept there during the entire operation. If a very heavy oil is being dealt with, the operation may be commenced with water previously heated to 120° instead of with cold water.

Explanatory Remarks.

For explanation as to the use of the pendulum see p. 86.

APPENDIX III.

DIRECTIONS FOR DRAWING THE SAMPLE AND PREPARING IT FOR TESTING IN TROPICAL CLIMATES.

(1) *Drawing the Sample.*—In all cases the testing officer, or some person duly authorised by him, shall personally superintend the drawing of the sample from an original unopened tin or other vessel.

An opening sufficiently large to admit of the oil being rapidly poured or siphoned from the tin or other vessel shall be made.

Two bottles, each of the capacity of about 40 fluid ounces, are to be filled with the oil. One of these, the contents of which are intended to be preserved for reference in case of need, is to be carefully corked, the cork being well driven home, cut off level with the neck, and melted sealing-wax worked into it. The other bottle may be either stoppered or corked.

(2) *Preparing the Sample for Testing.*—About 10 fluid ounces of the oil, sufficient for three tests, are transferred from the bottle into which the sample has been drawn to a pint flask or bottle, which is to be immersed in water artificially cooled, until a thermometer, introduced into the oil, indicates a temperature not exceeding 50° F.

DIRECTIONS FOR PREPARING AND USING THE TEST APPARATUS IN TROPICAL CLIMATES.

(3) *Preparing the Water-Bath.*—The water-bath is filled by pouring water into the funnel until it begins to flow out at the overflow pipe. The temperature of the water at the commencement of each test, as indicated by the long-bulb thermometer, is to be 130° F., and this is attained in the first instance by mixing hot and cold water, either in the bath or in a vessel from which the bath is filled, until the thermometer which is provided for testing the temperature of the water gives the proper indication; or the water is heated by means of a spirit-lamp (which is attached to the stand of the apparatus) until the required temperature is indicated.

(4) *Preparing the Test-Lamp.*—The test-lamp is fitted with a piece of cylindrical wick of such thickness that it fills the wick-holder, but may readily be moved to and fro for the purpose of adjusting the size of the flame. In the body of the lamp, upon the wick, which is coiled within it, is placed a small tuft of cotton wool, moistened with petroleum, any oil not absorbed by the wool being removed. When the lamp has been lighted, the wick is adjusted by means of a pair of forceps or a pin, until the flame is the size of the bead fixed on the cover of the oil-cup; should a particular test occupy so long a time that the flame begins to get smaller, through the supply of oil in the lamp becoming exhausted, three or four drops of petroleum are allowed to fall upon the tuft of wool in the lamp from the dropping-bottle or pipette provided for the purpose. This can be safely done without interrupting the test.*

(5) *Filling the Oil-Cup.*—Before the oil-cup is filled, the lid is to be made ready for being placed upon the cup—*i.e.*, the round-bulb thermometer is to be inserted into the socket (so that the projecting rim of the collar with which it is fitted touches the edge of the socket), and the test-lamp is to be placed in position. The oil-cup, having been previously cooled by placing it bottom downwards in water at a temperature not exceeding 50° F., is now to be rapidly wiped dry, placed on a level surface in a good light, and the oil to be tested is poured in without splashing until its surface is level with the point of the gauge which is fitted in the cup. The lid is then put on the cup at once, and pressed down so that its edge rests on the rim of the cup.

(6) *Application of the Test.*—The water-bath, with its thermometer in position, is placed in some locality where it is not exposed to currents of air, and where the light is sufficiently subdued to admit of the size of the entire test-flame being compared with that of the bead on the cover. The cup is carefully lifted, without shaking it, and placed in the bath, the test-lamp is lighted, and the clockwork wound up by turning the key.† The thermometer in the oil-cup is now watched, and when the temperature has reached 56° F. the clockwork is set in motion by pressing the trigger

If no flash takes place, the clockwork is at once re-wound, and the trigger pressed at 57° F., and so on at every degree rise of temperature until the flash occurs, or until a temperature of 95° F. has been reached.

If the flash takes place at any temperature below 77° F., the

* These suggestions will be found of value in the use of the instrument in a temperate climate also.

† This refers to the Abel-Pensky apparatus.

temperature at which it occurs is to be recorded. The fresh portions of the sample are then to be successively tested in a similar manner and the results recorded. If no greater difference than 2° F. exists between any two of the three recorded results, each result is to be corrected for atmospheric pressure, as hereafter described, and the average of the three corrected results is the flashing-point of the sample. In the event of there being a greater difference than 2° F. between any two of the results, the series of tests is to be rejected, and a fresh series of three similarly obtained, and so on until a sufficiently concordant series is furnished, when the results are to be corrected and the average taken in the manner already described.

No flash which takes place within 8° of the temperature at which the testing is commenced shall be accepted as the true flashing-point of the sample tested. In the event of a flash occurring at or below 64° when the test is applied in the manner above described, the next testing shall be commenced 10° lower than the temperature at which the flash had been previously obtained—that is to say, at 54° or thereunder, and this procedure shall be continued until the results of three consecutive tests do not show a greater difference than 2°.

If a temperature of 76° F. has been reached without a flash occurring, the application of the test-flame is to be continued until a temperature of 95° F. has been reached. If no flash has occurred up to this point, and if the petroleum is declared to be imported subject to the provisions of the Act,* the tests shall not be continued, and the testing officer shall certify that the petroleum has a flashing-point of over 95° and is not dangerous. But if the petroleum is oil ordinarily used for lubricating purposes, and is declared to have its flashing-point at or above 200°, or is oil to which a notification of the Governor in Executive Council exempting it from the operation of the Act will be applicable in the event of the flashing-point being found to be at or above 120°, the test shall be continued as follows: The oil-cup is to be removed from the water-bath, and the temperature of the water in the water-bath is to be reduced to 95° F. by pouring cold water into the funnel (the hot water escaping by the overflow pipe). The air chamber is then to be filled to a depth of 1½ inch with water at a temperature of about 95° F., the oil-cup is to be replaced in the water-bath, and the spirit-lamp attached to the water-bath is to be lighted and placed underneath. The test-flame is then to be again applied from 96° F., at every degree rise of temperature as indicated by the thermometer in the oil-cup, until a flash takes

* The Indian Petroleum Act is here referred to.

place, or until a temperature of 200° F. or 120° F., as the case may be, has been reached. If during this operation the test-flame appears to diminish in size, the lamp is to be replenished in the manner prescribed at (4) without interrupting the test.

If a flash occurs at any temperature between 76° and 200° F. the temperature at which it occurs, subject to correction for atmospheric pressure, is the flashing-point of the sample.

In repeating a test, a fresh sample of oil must always be used, the tested sample being thrown away, and the cup must be wiped dry from any adhering oil, and cooled, as already described, before receiving the fresh sample.

(7) *Correction for Atmospheric Pressure.*—As the flashing-point of an oil is influenced by changes in atmospheric pressure to an average extent of 1·6° F. for every inch of the barometer, a correction of the observed flashing-point may become necessary. The height of the barometer must, therefore, be determined at the time of making the test for the flashing-point. An aneroid barometer is supplied for this purpose. To facilitate the correction of a flashing-point for pressure a table is appended,* giving flashing-points of oils ranging from 65° to 80° F., under pressures ranging from 27 to 31 inches of mercury.

The table is used in the following manner :—

Example.—An oil has given a flashing-point of 71°, the barometer being at 28·6 in.; take the nearest number to 71° in the vertical column headed 28·6. This number is 70·8. Substitute for this the number in the same horizontal line in the column headed 30 (the normal height of the barometer). The substituted number—*i.e.*, the true flashing-point of the oil—is 73°.

* This table will be found in Appendix VIII.

APPENDIX IV.

PETROLEUM (HAWKERS) ACT, 1881.

Chapter 67.

A.D. 1881.

An Act to regulate the hawking of Petroleum and other substances of a like nature. [August 27, 1881.]

Be it enacted by the Queen's most Excellent Majesty, by and with the advice and consent of the Lords Spiritual and Temporal, and Commons, in this present Parliament assembled, and by the authority of the same, as follows:

Power to hawk petroleum. 34 & 35 Vict. c. 105.

1. Any person who is licensed in pursuance of the Petroleum Act, 1871, to keep petroleum to which that Act applies may, subject to the enactments for the time being in force with respect to hawkers and pedlars, hawk such petroleum by himself or his servants.

Regulations for hawking petroleum.

2. With respect to the hawking of petroleum to which the Petroleum Act, 1871, applies, the following regulations shall be observed:

(1) The amount of petroleum conveyed at one time in any one carriage shall not exceed twenty gallons:

(2) The petroleum shall be conveyed in a closed vessel so constructed as to be free from leakage:

(3) The carriage in which the vessels containing the petroleum are conveyed shall be so ventilated as to prevent any evaporation from the petroleum mixing with the air in or about the carriage in such proportion as to produce or be liable to produce an explosive mixture:

(4) Any fire or light or any article of an explosive or highly inflammable nature shall not be brought into or dangerously near to the carriage in which the vessels containing the petroleum are conveyed:

(5) The carriage in which the vessels containing the petroleum are conveyed shall be so constructed or fitted that the petroleum

cannot escape therefrom in the form of liquid, whether ignited or otherwise:

(6) Proper care shall be taken to prevent any petroleum escaping into any part of a house or building, or of the curtilage thereof, or into a drain or sewer:

(7) The petroleum shall be stored in some premises licensed for keeping of petroleum and in accordance with the licence for such premises both every night and also when the petroleum is not in the course of being hawked:

(8) All due precautions shall be taken for the prevention of accidents by fire or explosion, and for preventing unauthorised persons having access to the vessels containing the petroleum, and every person concerned in hawking the petroleum shall abstain from any act whatever which tends to cause fire or explosion, and is not reasonably necessary for the purpose of such hawking:

(9) No article or substance of an explosive or inflammable character other than petroleum, nor any article liable to cause or communicate fire or explosion, shall be in the carriage while such carriage is being used for the purpose of hawking petroleum:

In the event of any contravention of this section with reference to any petroleum, the petroleum, together with the vessels containing and the carriage conveying the same, shall be liable to be forfeited, and in addition thereto the licensee by whom or by whose servants the petroleum was being hawked shall be liable on summary conviction to a penalty not exceeding twenty pounds.

Provided that—

(1) Where some servant of the licensee or other person has in fact committed the offence, such servant or other person shall be liable to the same penalty as if he were the licensee:

(2) Where the licensee is charged with a contravention of this section, he shall be entitled upon information duly laid by him to have any other person whom he charges as the actual offender brought before the court at the time appointed for hearing the charge, and if the licensee proves to the satisfaction of the court that he had used due diligence to enforce the execution of this section, and that the said other person had committed the offence in question without his knowledge, consent, or connivance, the said other person shall be summarily convicted of such offence, and the licensee shall be exempt from any penalty.

Any petroleum other than that to which the Petroleum Act, 1871, applies while in any carriage used for the hawking of petroleum to which the Petroleum Act, 1871, applies, shall for the

purposes of this section be deemed to be petroleum to which the Petroleum Act, 1871, applies.

Modification of conditions of licence under 34 & 35 Vict. c. 105.

3. Any conditions annexed to a licence granted in pursuance of the Petroleum Act, 1871, either before or after the passing of this Act, shall, so far as they are inconsistent with this Act, be void, but save as aforesaid nothing in this Act shall affect the application to a licensee of the provisions of the Petroleum Act, 1871, or of any licence granted thereunder.

Power of constable as to prevention of offences.

4. Where a constable or any officer authorised by the local authority has reasonable cause to believe that a contravention of this Act is being committed in relation to any petroleum, he may seize and detain such petroleum and the vessels and carriage containing the same, until some court of summary jurisdiction has determined whether there was or not a contravention of this Act, and section thirteen of the Petroleum Act, 1871, shall apply to such constable and officer as if he were the person named in the warrant mentioned in that section, and as if the seizure were a seizure in pursuance of that section.

Saving of rights of municipal boroughs.

5. Nothing in this Act contained shall extend to authorise the hawking of petroleum within the limits of any municipal borough in which, by any lawful authority, such hawking shall have been or may hereafter be forbidden.

6. For the purposes of this Act—

Definitions.

The expression "carriage" includes any carriage, waggon, cart, truck, vehicle, or other means of conveyance by land, in whatever manner the same may be drawn or propelled; and

A person shall be deemed for the purposes of this Act to hawk petroleum if by himself or his servants he goes about carrying petroleum to sell, whether going from town to town or to other men's houses, or selling it in the streets of the place of his residence or otherwise, and whether with or without any horse or other beast bearing or drawing burden.

Short title and construction of Act.

7. This Act may be cited as the Petroleum (Hawkers) Act, 1881.

This Act shall be construed as one with the Petroleum Acts, 1871 and 1879, and together with those Acts may be cited as the Petroleum Acts, 1871 to 1881.

APPENDIX V.

MODEL CODE.

Petroleum Acts, 1871 to 1881.

Harbour of

BY-LAWS

Made by the with the sanction of the Board of Trade.

19 .

(1) These By-laws shall apply to all parts of the Harbour of within the jurisdiction of the the limits of whose jurisdiction are set forth in the Schedule hereto. **Application.**

(2) The expressions contained in these By-laws shall have the meanings respectively assigned to them in the Petroleum Acts, 1871 and 1879, and in this By-law. **Interpretation.**

"Petroleum" shall have the same meaning as "petroleum to which this Act applies" in the Petroleum Act, 1871, as amended by the Petroleum Act, 1879, and shall not include carbide of calcium.

"Petroleum ship" shall mean any ship having on board petroleum as cargo.

"Owner" shall mean Owner or Master of the petroleum ship or the owner of the petroleum.

"Harbour Master" shall mean the Harbour Master or other officer duly appointed by the Harbour Authority or any person having authority to act in such capacity.

"Quay" shall mean any quay, pier, jetty, wharf, landing stairs, shore or other landing place within the Harbour.

(3) The Master of every petroleum ship shall, on nearing the Harbour, and during the time that such ship remains in the Harbour, display by day a red flag not less than 3 feet square, and by night a red light, on the masthead (or, if the said ship has no mast, on a staff). **Red flag or light.**

(4) The Owner of every petroleum ship on entering the Harbour **Notice.**

shall, without delay, inform the Harbour Master of the quantity of petroleum on his ship and of the manner in which such petroleum is stored, and this shall be deemed to be the notice to the harbour authority required by Section 5 of the Petroleum Act, 1871.

Berthing of ship.

(5) The Master of every petroleum ship shall anchor or moor his ship only at such place as the Harbour Master shall from time to time direct, and shall not remove his ship therefrom, except for the purpose of leaving the Harbour, without the written order or permission of the Harbour Master. No petroleum ship shall be anchored or moored at any place other than that approved by the Harbour Master, whether for the purpose of landing or shipping petroleum or otherwise.

General Rules for landing petroleum.

(6) The following General Rules in respect of the unloading of petroleum within the Harbour shall be duly observed:—

(*a*) Before any petroleum is landed the Owner shall give due notice to the Harbour Master of the time and place of such landing.

(*b*) No petroleum shall be landed at any Quay other than such Quay as the Harbour Master shall from time to time direct.

(*c*) Before any petroleum contained in barrels, or other vessels, is landed, the holds of a petroleum ship shall be thoroughly ventilated, and after all petroleum has been removed from any petroleum ship, the holds and tanks shall be thoroughly cleansed.

Provided that this By-law shall not be deemed to require the cleansing of the tanks of a tank steamer which leaves the Harbour immediately after the discharge of the cargo, and of which the tanks are closed up immediately after such discharge.

(*d*) Petroleum shall not be landed except between the hours of sunrise and sunset.

(*e*) From the time when the holds or tanks of a petroleum ship are first opened for the purpose of landing petroleum until such time as all petroleum shall have been removed from such ship, and the holds or tanks shall have been thoroughly cleansed as required by this By-law, there shall be no fire or artificial light on board such ship or at or near the place where the petroleum is being landed.

Provided that this By-law shall not prevent the use of a safety lamp of a construction approved by the Harbour Master.

(*f*) The Owner shall not allow any smoking at or near the place

where petroleum is being landed, nor shall he allow any person engaged in such landing to carry fuzees, matches, or appliances whatsoever for producing ignition.

(*g*) No petroleum contained in casks, barrels, or other vessels shall be landed in the Harbour, unless such vessels are staunch and free from leakage, and are of such strength and construction as not to be liable to be broken or to leak, except in case of gross carelessness or extraordinary accident.

(*h*) When the landing of petroleum has been commenced, such landing shall be proceeded with with due diligence.

(*i*) No petroleum shall be landed at any Quay until the ship or carriage by which the same is to be removed therefrom shall be at the place in readiness to receive the same, and all petroleum landed in the Harbour shall be forthwith removed therefrom, or to some duly licensed place of storage.

(*j*) No petroleum shall be discharged or allowed to escape into the waters of the Harbour.

(*k*) The Owner shall take all due precautions for the prevention of accident by fire in landing petroleum.

(7) Two or more petroleum ships shall not, except for purpose of transhipment, lie within 100 feet of one another, unless, in the opinion of the Harbour Master, it is impracticable to maintain such distance.

(8) Every petroleum ship shall be watched by a competent person on board such ship until all petroleum on board shall have been landed, and every petroleum ship shall at all times have on board a responsible person to carry out and give effect to the provisions of these By-laws.

(9) The Owner shall, when so required by the Harbour Master, or other officer duly appointed by the Harbour Authority, or by any police constable, show to such officer or constable all petroleum under his control or upon his vessel, and shall afford every reasonable facility to enable such officer or constable to inspect and examine such petroleum so as to ascertain whether these By-laws are duly observed.

Where any ship or cargo is moored, landed, and otherwise dealt with in contravention of any of the above By-laws, the Owner and Master of such ship and the Owner of such cargo, as the case may be, shall each incur a penalty not exceeding fifty pounds for each day during which such contravention continues, and it shall be lawful for the Harbour Master or any other person acting under the orders of the Harbour Anthority to cause such ship or cargo to be removed, at the expense of the owner thereof, to such place as may be in conformity with the said By-law.

APPENDIX VI.

MEMORANDUM ISSUED BY LONDON COUNTY COUNCIL AND FORMS OF LICENCE FOR PETROLEUM AND CARBIDE OF CALCIUM.

LONDON COUNTY COUNCIL.

PUBLIC CONTROL DEPARTMENT.

Petroleum Acts, 1871 to 1881.

ABSTRACT OF THE REGULATIONS AS TO THE KEEPING, SALE, CONVEYANCE, AND HAWKING OF PETROLEUM IN THE COUNTY OF LONDON.

This Abstract has no legal validity, and is intended only for the information and guidance of the persons concerned. For further information reference should be made to the Petroleum Acts, 1871 *and* 1879, *to the Petroleum* (*Hawkers*) *Act*, 1881, *and to the Locomotives on Highways Act*, 1896, *and the Regulations of the Secretary of State thereunder of April* 26, 1900.

GENERAL.

Definition of petroleum.

1. Petroleum to which the Acts apply means "any rock oil, Rangoon oil, Burmah oil, oil made from Petroleum, coal, schist, shale, peat, or other bituminous substance, and any products of petroleum, or any of the above-mentioned oils," which, when tested in the prescribed manner, give off an inflammable vapour at a temperature of less than 73 degrees of Fahrenheit's thermometer.

This definition includes any composition such as varnish, paint, or indiarubber solution, which contains petroleum spirit.

2. Throughout this abstract, petroleum to which the Acts apply is called "Petroleum Spirit"; and all other petroleum is called "Petroleum Oil."

3. Where petroleum is—

Labelling vessels.

(*a*) Kept at any place (except during the seven days next after importation); or

(*b*) Sold or exposed for sale,
the vessel containing it shall have a label stating in conspicuous characters the description of petroleum, with the addition of the words "highly inflammable," and also the name and address of the owner or vendor.

Keeping petroleum spirit.

4. Petroleum spirit can only be kept in pursuance of a licence granted by the Council, except as follows:

(*a*) Not exceeding three gallons may be kept in separate glass, earthenware, or metal vessels, securely stopped, each of which must not contain more than one pint.

(*b*) When it is kept or used for the purpose of light locomotives in accordance with the Regulations as to petroleum made by the Secretary of State.

Licences.

Applications.

5. Application to the Council for a licence must be made upon the form provided for the purpose, which can be obtained by application in writing, addressed to the Chief Officer, Public Control Department of the London County Council, 6 Waterloo Place, Pall Mall, S.W.

Fees.

6. Every application must be accompanied by a fee of 5*s*. in money, or, if sent through the post, by cheque, or Postal Order payable to the order of the London County Council. The fee will be returned to the applicant if the licence be not granted.

Plans.

7. Where the application is for a licence to store 50 gallons or more there must also be sent a plan, drawn to the scale of one-eighth of an inch to a foot, and showing the proposed place and means of storage, and also showing the buildings, &c., within 50 feet of such place.

Particulars in application.

8. Every application must state—

(*a*) The quantity of petroleum spirit which the applicant desires to keep;

(*b*) The proposed place and method of storage;

(*c*) Particulars of manufacturing processes (if any) in which the spirit is to be used.

Mode of storage.

9. Petroleum spirit should, whenever possible, be stored in one of the following methods:

(*a*) In a strong metal tank sunk into the ground at a suitable place, and covered with earth or concrete. The tank to have no openings but for the pipes through which the petroleum spirit is pumped.

(*b*) In a concrete, stone, brick, or iron store (partially sunk into the ground where possible), the lower part so constructed

as to form a tank capable of receiving, in case of accident, all the petroleum contained in the store. The store to be ventilated sufficiently to prevent the accumulation therein of an inflammable vapour, and all ventilating openings to be protected by strong wire gauze.

The Council, however, grants licences to keep quantities not exceeding 10 gallons of petroleum spirit in yards or other suitable situations, on condition that a place of storage having a superficial area measuring at least 5 feet by 5 feet is provided, and is exclusively appropriated to the purpose, and that such place of storage is not within any inhabited building.

In cases where the foregoing methods of storage cannot be adopted, the Council may grant licences under special conditions, provided the means of storage and precautions for safety proposed are considered satisfactory.

General conditions in licences.

10. The following are the usual general conditions contained in petroleum licences granted by the Council.

(1) That the total quantity of petroleum kept do not exceed

(2) That petroleum be exclusively contained in strong metal vessels, fitted with screw caps, and with secure taps, so constructed and connected as to prevent leakage or the escape of vapour.

(3) That there be kept painted in conspicuous characters on every storage vessel containing petroleum the description of petroleum, with the addition of the words "highly inflammable."

(4) That vessels containing petroleum be kept only in

(*Here follows description of the place of storage.*)

(5) That any vessel containing petroleum be only opened upon the licensed premises, at or immediately adjoining the place of storage, and for the time necessary for drawing off the petroleum; and that during such drawing off every reasonable precaution be adopted for preventing the escape of petroleum or the vapour therefrom.

(6) That no substance other than petroleum be deposited or kept in the place of storage above described.

(7) That all petroleum received upon the premises be at once taken to the place of storage; and that petroleum taken from the place of storage for delivery or otherwise be at once removed from the premises.

(8) That the licensee do take effectual precautions for preventing unauthorised persons and all persons under the age of 15 years from obtaining access to the place of storage.

(9) That there be no fire, forge, furnace, or similar source of

danger, or any storage of explosives within 20 feet, or of highly inflammable material within 10 feet, of the place of storage, unless separated therefrom by a wall or screen of sufficient strength and height to prevent the communication of fire, and that [such] artificial light as would ignite inflammable vapour be not at any time taken into or near the place of storage.

(10) That petroleum be only received into or supplied from the licensed premises between sunrise and sunset.

(11) That not less than one bushel of sand be kept with every vessel in which petroleum is stored, and that some portion of this be constantly kept immediately under the tap of the vessel.

(12) That petroleum be only conveyed to or from the licensed premises in closed vessels, so constructed as to be entirely free from leakage, and that gunpowder or other article likely to cause fire or explosion be not carried in a vehicle in which petroleum is being conveyed.

(13) That the arrangements for storage, as approved by the Council, and as seen by the Council's inspector last before the granting of this licence, be in all respects kept and maintained, unless the consent of the Council is given in writing to any departure therefrom.

(14) That every authorised officer of the Council be at all times allowed free access to the premises of the licensee, for the purpose of ascertaining if the above conditions are properly observed; and that the licensee do, by himself or his representatives, give any assistance for that purpose which such officer may require.

11. Licences are granted for periods not exceeding one year, and prior to expiration application must be made for their renewal. Notice of the expiration, and a form of application for renewal, is sent to each licensee at the proper time. **Duration of licence.**

Conveyance of Petroleum Spirit.

12. Where petroleum spirit is sent or conveyed, the vessel containing it shall have a label stating in conspicuous characters the description of petroleum with the addition of the words "highly inflammable," and also the name and address of the sender. **Conveyance of petroleum. spirit.**

13. Petroleum spirit conveyed to or from licensed premises must be conveyed in accordance with the conditions of the licence.

Hawking Petroleum.

14. Any person licensed to keep petroleum spirit may, subject to the enactments as to hawkers and pedlars, and to the following regulations, hawk petroleum by himself or his servants. **Hawking petroleum.**

Regulations as to hawking.

15. Section 2 of the Petroleum (Hawkers) Act, 1881, provides with respect to the hawking of petroleum, that the following regulations shall be observed—

(1) The amount of petroleum conveyed at one time in any one carriage shall not exceed twenty gallons.

(2) The petroleum shall be conveyed in a closed vessel, so constructed as to be free from leakage.

(3) The carriage in which the vessels containing the petroleum are conveyed shall be so ventilated as to prevent any evaporation from the petroleum mixing with the air in or about the carriage in such proportion as to produce, or be liable to produce, an explosive mixture.

(4) Any fire or light, or any article of an explosive or highly inflammable nature, shall not be brought into or dangerously near to the carriage in which the vessels containing the petroleum are conveyed.

(5) The carriage in which the vessels containing the petroleum are conveyed shall be so constructed or fitted that the petroleum cannot escape therefrom in the form of liquid, whether ignited or otherwise.

(6) Proper care shall be taken to prevent any petroleum escaping into any part of a house or building, or of the curtilage thereof, or into a drain or sewer.

(7) The petroleum shall be stored in some premises licensed for the keeping of petroleum, and in accordance with the licence for such premises, both every night and also when the petroleum is not in the course of being hawked.

(8) All due precautions shall be taken for the prevention of accidents by fire or explosion, and for preventing unauthorised persons having access to the vessels containing the petroleum, and every person concerned in hawking the petroleum shall abstain from any act whatever which tends to cause fire or explosion, and is not reasonably necessary for the purpose of such hawking.

(9) No article or substance of an explosive or inflammable character other than petroleum, nor any article liable to cause or communicate fire or explosion, shall be in the carriage while such carriage is being used for the purpose of hawking petroleum.

When petroleum oil is in a carriage used for hawking petroleum spirit, such petroleum oil is deemed to be petroleum within the Act.

Petroleum Spirit for use for Motor Cars.

Petroleum spirit for motor cars.

16. Petroleum spirit for use for motor cars may be kept without a licence if the restrictions laid down in the Regulations of the Secretary of State under the Locomotives on Highways Act (given in full in Appendix IX.) are strictly observed.

Where these regulations cannot be observed, or where it is intended to also *sell* spirit for use for motor cars, a licence is necessary.

INSPECTION.

17. Any dealer who refuses to show to any officer authorised by the Council every or any place or all or any of the vessels in which petroleum or petroleum oil in his possession is kept, or to give him such assistance as he may require for examining the same, or to give to such officer samples of such petroleum or petroleum oil on payment of the value of such samples, or who wilfully obstructs the Council, or any officer of the Council, in the execution of this Act, shall incur a penalty not exceeding twenty pounds. **Refusing information or obstructing officer.**

ALFRED SPENCER,
Chief Officer.

6 Waterloo Place,
Pall Mall, S.W.
May 1900.

LONDON COUNTY COUNCIL.

PUBLIC CONTROL DEPARTMENT.

Carbide of Calcium.

ABSTRACT OF THE REGULATIONS AS TO THE KEEPING, SALE, AND CONVEYANCE OF CARBIDE OF CALCIUM IN THE COUNTY OF LONDON.

The Abstract has no legal validity, and is intended only for the information and guidance of the persons concerned. For further information reference should be made to the Petroleum Acts, and to the Orders in Council dated February 26, 1897, *and July* 7, 1897.

GENERAL.

1. By an Order in Council, dated February 26, 1897, carbide of calcium can only be kept in pursuance of a licence granted by the local authority.

2. By a further Order in Council, dated July 7, 1897, not exceeding 5 lbs. of carbide may be kept without licence, provided it is kept in separate substantial hermetically-closed metal vessels containing no more than 1 lb. each. **Exemption.**

NOTE.—*The order does not provide for the keeping of any quantity except in a closed vessel. Only one vessel should, therefore, be opened at a time, and the quantity of carbide, not exceeding* 1 *lb., required for use, should be at once placed in the generator, which should be immediately closed. If any carbide remain in the storage vessel, such vessel should be at once re-closed.*

Labelling vessels.

3. Where carbide of calcium is:

(*a*) Kept at any place; or

(*b*) Sold or exposed for sale,

the vessel containing it shall bear a label stating in conspicuous characters the words "Carbide of calcium," "Dangerous if not kept dry," and with the following caution:—"The contents of this package are liable if brought into contact with moisture to give off a highly inflammable gas," and also the name and address of the owner or vendor.

LICENCES.

Applications.

4. Application to the Council for a licence to keep carbide of calcium at any place in the County of London (except the City of London) must be made upon the form provided for the purpose, which can be obtained by application in writing, addressed to the Chief Officer, Public Control Department of the London County Council, 6 Waterloo Place, S.W.

Fees.

5. Every application must be accompanied by a fee of 5s. in money, or, if sent through the post, by cheque or postal order for that amount payable to the order of the London County Council. The fee will be returned to the applicant if the licence be not granted.

Particulars in application.

6. Every application must state:

(*a*) The quantity of carbide of calcium which the applicant desires to keep;

(*b*) The proposed place and method of storage;

(*c*) If the carbide is only to be kept for sale in closed vessels, or if it is to be used in the manufacture of acetylene gas.

Mode of storage.

7. Carbide of calcium should be kept in strong metal vessels, and—

(*a*) Such vessels should be so constructed and closed as to prevent the admission of water or atmospheric moisture.

(*b*) Such vessels should only be opened for the time necessary for the removal of any required quantity of carbide, or for the refilling of the vessels.

(*c*) No one vessel should have a greater capacity than 3696 cubic inches (equal to a cylindrical vessel 14 inches in diameter and 24 inches in depth).

(*d*) Every vessel of a greater capacity than 2 lbs. should be provided with a lock or be placed in a locked receptacle so as to prevent unauthorised persons gaining access to the contents.

(*e*) Copper should not be used in the construction of vessels for containing carbide.

Place of storage.

8. Vessels containing carbide of calcium should not be kept inside dwelling-houses, but preferably in dry and well-ventilated out-buildings.

Small quantities.

9. Small quantities of carbide for sale or immediate use will, however, be allowed in shops, dwellings or workshops, upon licensed premises, if the arrrangements are satisfactory.

Purity of the carbide.

10. The Council proposes only to grant licences to keep carbide of calcium which is pure (in a commercial sense), *i.e.*, which contains no impurities liable to generate phosphoretted or siliciuretted hydrogen so as to render the gas evolved liable to ignite spontaneously.

Acetylene gas.

11. Where carbide of calcium is kept for the manufacture of acetylene gas, it is desirable that such of the following precautions for ensuring safety as are applicable to the circumstances should be adopted:

Place of manufacture.

(*a*) Every apparatus for generating and storing acetylene gas should be placed in an outbuilding. (This does not apply to portable apparatus holding a charge of less than 2 lbs. of carbide.)

(*b*) Such building should be separated as far as may be practicable from inhabited buildings, and should be well ventilated.

(*c*) No fire or such artificial light as would ignite inflammable gas should be taken into or near the building or place where a gas-making apparatus is situate.

Nature of apparatus.

12. Every apparatus (including generator and gas-holder) used for acetylene gas should as far as practicable be constructed and used so as to provide against the special risk, *i.e.*—

(*a*) Copper should not be used in any part of the apparatus.

(*b*) The various parts should be of adequate strength.

(*c*) Escape of gas from the apparatus should be carefully guarded against.

(*d*) Satisfactory provision should be made against dangerous development of heat.

(*e*) Satisfactory provision should be made against undue pressure by the employment of an adequate safety valve connected with a pipe discharging into the open air, and a suitable pressure gauge should be attached to the apparatus.

(*f*) Provision should be made for the residue of the carbide being mixed with at least ten times its bulk of water on being removed from the apparatus.

(*g*) No person should have charge of an apparatus until he has been properly instructed in its management.

Duration of licence.

13. Licences are granted for keeping carbide of calcium for periods not exceeding one year, and prior to expiration application must be made for their renewal. Notice of the expiration, and a form of application for renewal, is sent to each licensee at the proper time.

Conveyance of Carbide of Calcium.

Conveyance of carbide of calcium.

14. Where carbide of calcium is sent or conveyed, the vessel containing it shall bear a label stating in conspicuous characters the words "Carbide of calcium," "Dangerous if not kept dry," and with the following caution:—"The contents of this package are liable if brought into contact with moisture to give off a highly inflammable gas," and also the name and address of the sender.

15. Carbide of calcium conveyed to or from licensed premises must be conveyed in accordance with the conditions of the licence.

Inspection.

Refusing information or obstructing officer.

16. Any dealer who refuses to show to any officer authorised by the Council every or any place or all or any of the vessels in which carbide of calcium in his possession is kept, or to give him such assistance as he may require for examining the same, or to give to such officer samples of such carbide of calcium on payment of the value of such samples, or who wilfully obstructs the Council, or any officer of the Council, in the execution of these Acts and the Orders made thereunder, is liable to a penalty not exceeding twenty pounds.

Alfred Spencer,
Chief Officer.

6 Waterloo Place, S.W.
April 21, 1899.

LONDON COUNTY COUNCIL.

A

(Storage place licence.)

Reg. No.

Petroleum Acts, 1871 to 1881.

PETROLEUM LICENCE.

PURSUANT to the provisions of the Petroleum Acts, 1871 to 1881, the London County Council doth hereby, at the request of M____________________ grant licence to__________ for the period of twelve calendar months from the________________________ to keep__________________ gallons of petroleum to which the Acts apply, and as defined in the said Acts, on the premises situate at____________________ in the parish of____________________ and within the County of London, subject to the conditions following, that is to say—

(1) That the vessel or vessels containing the petroleum be kept in a place of storage having a superficial area measuring at least 5 feet by 5 feet, that such place of storage be exclusively appropriated to the purpose, and that it be not within any inhabited building.

(2) That the place of storage aforesaid be in all respects kept and maintained in the same condition that it was in when inspected by an authorised officer of the Council last before the granting of this licence.

(3) That there be no fire, forge, furnace, or similar source of danger, or any storage of explosive within 20 feet, or of highly inflammable material within 10 feet, of such place of storage, unless separated therefrom by a wall or screen of sufficient strength and height to prevent the communication of fire.

(4) That no substance other than petroleum be deposited or kept in the place of storage.

(5) That petroleum be exclusively contained in strong metal vessels, the openings to which are covered with fine wire gauze and fitted with screw caps, and the vessels fitted with secure taps, so constructed and connected as to prevent leakage or the escape of vapour; and that such vessels and taps be kept in thoroughly good order.

(6) That there be kept painted in conspicuous characters on every storage vessel containing petroleum, the description of petroleum, with the addition of the words "highly inflammable."

(7) That petroleum be only conveyed to or from the licensed premises in closed vessels, so constructed as to be entirely free from leakage.

(8) That no petroleum be conveyed to or from the licensed premises in a vehicle in which gunpowder or other article likely to cause fire or explosion is also carried.

(9) That petroleum be only received in or supplied from the licensed premises between sunrise and sunset; and that no artificial light or fire, or article likely to cause fire, be at any time taken into or near the place of storage.

(10) That the vessels containing petroleum be only opened upon the licensed premises, at or immediately adjoining the place of storage and for the time necessary for drawing off the petroleum; and that during such drawing off every reasonable precaution be adopted for preventing the escape of petroleum or the vapour therefrom.

(11) That all the petroleum received upon the premises be at once taken to the place of storage; and that petroleum taken from the place of storage for delivery or otherwise, be at once removed from the premises.

(12) That the licensee do take effectual precautions for preventing unauthorised persons and all persons under the age of 15 years from obtaining access to the place of storage.

(13) That not less than a bushel of sand be kept with every vessel in which petroleum is stored, and that some portion of this be constantly kept immediately under the tap of the vessel.

(14) That due precaution be at all times taken for the prevention of accident from fire.

(15) That every authorised officer of the Council be at all times allowed free access to the premises of the licensee, for the purpose of ascertaining if the above conditions are properly observed; and that the licensee do, by himself or his representatives, give any assistance for that purpose which such officer may require.

Section 9 of the Petroleum Act, 1871, provides that "any licensee violating any of the conditions of his licence shall be deemed to be an unlicensed person."

By Order of the Council,

____

Clerk of the Council.

SPRING GARDENS, S.W.

This Licence is NOT transferable.

For regulations as to **hawking petroleum,** *see page* 241.

LONDON COUNTY COUNCIL. B

Petroleum Acts, 1871 to 1881.

(Store licence.)

PETROLEUM LICENCE.

Reg. No.

PURSUANT to the provisions of the Petroleum Acts, 1871 to 1881, the London County Council doth hereby, at the request of M____________________ grant licence to____________ for the period of twelve calendar months from the________________________ to keep____________________ gallons of petroleum to which the Acts apply, and as defined in the said Acts, on the premises situate at____________________ in the parish of____________________ and within the jurisdiction of the said Council, subject to the conditions following, that is to say—

(1) That the petroleum be kept only in a store substantially constructed entirely of concrete, stone, brick or iron, and having a fire-proof door which is to be kept locked at all times, except when petroleum is being placed in or removed from the store; that such store be not within any building, or abutting against a dwelling house; that the lower part of such store be so constructed as to form a tank capable of receiving and retaining, in case of accident, all the petroleum contained in the store; that the store be ventilated sufficiently to prevent the accumulation therein of an inflammable vapour, and that all ventilating openings be protected with strong wire gauze.

(2) That the place of storage aforesaid be in all respects kept and maintained in the same condition that it was in when inspected by an authorised officer of the Council last before the granting of this licence.

(3) That there be no fire, forge, furnace, or similar source of danger, or any storage of explosives within 20 feet, or of highly inflammable material within 10 feet, of such place of storage, unless separated therefrom by a wall or screen of sufficient strength and height to prevent the communication of fire.

(4) That no substance other than petroleum be deposited or kept in the place described in the first condition of this licence.

(5) That, unless otherwise specially provided for in the first condition of this licence, all petroleum kept upon the premises be exclusively contained in strong metal vessels, the openings to

which are covered with fine wire gauze and fitted with screw caps, and with secure taps, so constructed and connected as to prevent leakage or the escape of vapour; and that such vessels and taps be kept in thoroughly good order.

(6) That there be kept painted in conspicuous characters on every storage vessel containing petroleum the description of petroleum, with the addition of the words "highly inflammable."

(7) That petroleum be only conveyed to or from the licensed premises in closed vessels, so constructed as to be entirely free from leakage.

(8) That no petroleum be conveyed to or from the licensed premises in a vehicle in which gunpowder or other article likely to cause fire or explosion is also carried.

(9) That petroleum be only received in or supplied from the licensed premises between sunrise and sunset; and that no artificial light or fire, or article likely to cause fire, be at any time taken into or near the place of storage.

(10) That the vessels containing petroleum be only opened upon the licensed premises, at or immediately adjoining the place of storage, and for the time necessary for drawing off the petroleum; and that during such drawing off every reasonable precaution be adopted for preventing the escape of petroleum or the vapour therefrom.

(11) That all petroleum received upon the premises be at once taken to the place of storage; and that petroleum taken from the place of storage, for delivery or otherwise, be at once removed from the premises.

(12) That the licensee do take effectual precautions for preventing unauthorised persons and all persons under the age of 15 years from obtaining access to the place of storage.

(13) That not less than a bushel of sand be kept with every vessel in which petroleum is stored, and that some portion of this be constantly kept immediately under the tap of the vessel.

(14) That due precaution be at all times taken for the prevention of accident from fire.

(15) That every authorised officer of the Council be at all times allowed free access to the premises of the licensee, for the purpose of ascertaining if the above conditions are properly observed; and that the licensee do, by himself or his representatives, give any assistance for that purpose which such officer may require.

By Order of the Council,

Clerk of the Council.

Section 9 of the Petroleum Act, 1871, provides that "any licensee violating any of the conditions of his licence shall be deemed to be an unlicensed person."

This Licence is NOT transferable.

***For regulations as to* labelling vessel *containing* Petroleum, *and as to* hawking Petroleum, *see page* 241.**

LONDON COUNTY COUNCIL.

C

Petroleum Acts, 1871 to 1881.

(Special Licence.)

PETROLEUM LICENCE.

Reg. No.

PURSUANT to the provisions of the Petroleum Acts, 1871 to 1881, the London County Council doth hereby, at the request of M____________________________grant Licence to________________for the period of twelve calendar months from the____________________________________to keep________________________gallons of petroleum to which the Acts apply, and as defined in the said Acts, on the premises situate at______________________________in the parish of____________________________and within the jurisdiction of the said Council, subject to the conditions following, that is to say—

(1) That the petroleum be kept only in____________________

____

____

____

____

____

(2) That the place of storage aforesaid be in all respects kept and maintained in the same condition that it was in when inspected by an authorised Officer of the Council last before the granting of this licence.

(3) That there be no fire, forge, furnace, or similar source of danger, or any storage of explosives within twenty feet, or of highly inflammable material within ten feet, of such place of storage, unless separated therefrom by a wall or screen of sufficient strength and height to prevent the communication of fire.

(4) That no substance other than petroleum be deposited or kept in the place described in the first condition of this licence.

(5) That, unless otherwise specially provided for in the first condition of this licence, all petroleum kept upon the premises be exclusively contained in strong metal vessels, the openings to which are covered with fine wire gauze and fitted with screw caps, and with secure taps, so constructed and connected as to prevent leakage or the escape of vapour; and that such vessels and taps be kept in thoroughly good order.

(6) That there be kept painted in conspicuous characters on every storage vessel containing petroleum, the description of petroleum, with the addition of the words "highly inflammable."

(7) That petroleum be only conveyed to or from the licensed premises in closed vessels, so constructed as to be entirely free from leakage.

(8) That no petroleum be conveyed to or from the licensed premises in a vehicle in which gunpowder or other article likely to cause fire or explosion is also carried.

(9) That petroleum be only received in or supplied from the licensed premises between sunrise and sunset; and that no artificial light or fire, or article likely to cause fire, be at any time taken into or near the place of storage.

(10) That the vessels containing petroleum be only opened upon the licensed premises, at or immediately adjoining the place of storage, and for the time necessary for drawing off the petroleum; and that during such drawing off every reasonable precaution be adopted for preventing the escape of petroleum or the vapour therefrom.

(11) That all petroleum received upon the premises be at once taken to the place of storage; and that petroleum taken from the place of storage for delivery or otherwise, be at once removed from the premises.

(12) That the licensee do take effectual precautions for preventing unauthorised persons and all persons under the age of fifteen years from obtaining access to the place of storage.

(13) That not less than a bushel of sand be kept with every vessel in which petroleum is stored, and that some portion of this be constantly kept immediately under the tap of the vessel.

(14) That due precaution be at all times taken for the prevention of accident from fire.

(15) That every authorised Officer of the Council be at all times allowed free access to the premises of the licensee, for the purpose of ascertaining if the above conditions are properly observed; and

that the licensee do, by himself or his representatives, give any assistance for that purpose which such officer may require.

By Order of the Council,

____

Clerk of the Council.

Section 9 of the Petroleum Act, 1871, provides that "any Licensee violating any of the conditions of his Licence shall be deemed to be an unlicensed person."

This Licence is NOT transferable.

For regulations as to **labelling vessel** *containing* **Petroleum,** *and as to* **hawking Petroleum,** *see page* **241.**

LONDON COUNTY COUNCIL.

D

(Special licence. No. 2.)

Reg. No.

Petroleum Acts, 1871 to 1881.

PETROLEUM LICENCE.

PURSUANT to the provisions of the Petroleum Acts, 1871 to 1881, the London County Council doth hereby at the request of______________________________grant licence to__________________for the period of twelve calendar months from the______________________________to keep__________________gallons of petroleum, to which the Acts apply, and as defined in the said Acts, on the premises______________________________in the parish of______________________________and within the jurisdiction of the said Council, subject to the conditions following, that is to say—

That no fire, or any such artificial light as would ignite inflammable vapour, be at any time within or nearer than feet of the openings of buildings where petroleum is kept.

That vessels containing petroleum be only opened for the time absolutely necessary for the purposes of the business, and that every precaution be used for preventing the inflammable vapour from escaping from such vessels.

That the arrangements for the storage or use of petroleum as approved by the Council and as seen by the Council's Inspector last before the granting of this licence, be in all respects kept and main-

tained, unless the consent of the Council is given in writing to any departure therefrom.

That due precaution be at all times taken for the prevention of accident from fire.

That every authorised Officer of the Council be at all times allowed free access to the premises of the licensee, for the purpose of ascertaining if the above conditions are properly observed; and that the licensee do, by himself or his representatives, give any assistance for that purpose which such officer may require.

By Order of the Council,

Clerk of the Council.

SPRING GARDENS, S.W.

Section 9 of the Petroleum Act, 1871, provides that any "Licensee violating any of the conditions of his Licence shall be deemed to be an unlicensed person."

This Licence is NOT transferable.

E

Reg. No.

LONDON COUNTY COUNCIL.

Petroleum Acts, 1871 to 1881, and Order in Council, dated February 26, 1897.

PETROLEUM AND CARBIDE OF CALCIUM LICENCE.

PURSUANT to the provisions of the Petroleum Acts, 1871 to 1881, and of the Order in Council, dated February 26, 1897, the London County Council doth hereby at the request of ____________ ____ grant licence to ________________ for the period of twelve calendar months from the ____ to keep petroleum and carbide of calcium on the premises ____________ ____

in the parish of ________________________________ and within the jurisdiction of the said Council, subject to the conditions following, that is to say—

Petroleum.

(1) That the total quantity of petroleum kept do not exceed ______ ____

(2) That petroleum be exclusively contained in strong metal

vessels, fitted with screw caps, and with secure taps, so constructed and connected as to prevent leakage or the escape of vapour.

(3) That there be kept painted in conspicuous characters on every storage vessel containing petroleum, the description of petroleum, with the addition of the words "highly inflammable."

(4) That vessels containing petroleum be kept only in__________

____

____

____

____

____

(5) That any vessel containing petroleum be only opened upon the licensed premises, at or immediately adjoining the place of storage, and for the time necessary for drawing off the petroleum; and that during such drawing off every reasonable precaution be adopted for preventing the escape of petroleum or the vapour therefrom.

(6) That no substance other than petroleum be deposited or kept in the place of storage above described.

(7) That all petroleum received upon the premises be at once taken to the place of storage; and that petroleum taken from the place of storage for delivery or otherwise, be at once removed from the premises.

(8) That the licensee do take effectual precautions for preventing unauthorised persons and all persons under the age of fifteen years from obtaining access to the place of storage.

(9) That there be no fire, forge, furnace, or similar source of danger, or any storage of explosives within 20 feet, or of highly inflammable material within 10 feet, of the place of storage, unless separated therefrom by a wall or screen of sufficient strength and height to prevent the communication of fire, and that [such] artificial light as would ignite inflammable vapour be not at any time taken into or near the place of storage.

(10) That petroleum be only received into or supplied from the licensed premises between sunrise and sunset.

(11) That not less than one bushel of sand be kept with every vessel in which petroleum is stored, and that some portion of this be constantly kept immediately under the tap of the vessel.

(12) That petroleum be only conveyed to or from the licensed premises in closed vessels, so constructed as to be entirely free from leakage, and that gunpowder or other article likely to cause fire or explosion be not carried in a vehicle in which petroleum is being conveyed.

Carbide of calcium.

(13) That carbide of calcium which contains impurities liable to generate phosphoretted or siliciuretted hydrogen so as to render the gas evolved liable to ignite spontaneously, be not kept under this licence.

(14) That the total quantity of carbide of calcium kept on the premises at one time do not exceed ____________________

____

(15) That carbide of calcium be kept, sent or conveyed only in strong metal vessels, each of which shall be of a capacity not exceeding 3696 cubic inches, and be so constructed and closed as to prevent the admission of water or atmospheric moisture.

(16) That every vessel containing carbide of calcium shall bear a label stating in conspicuous characters the words, "Carbide of calcium," "Dangerous if not kept dry," and with the following caution—"The contents of this package are liable if brought into contact with moisture to give off a highly inflammable gas," and also the name and address of the owner or vendor in the case of carbide being kept, and the name and address of the sender when it is being conveyed.

(17) That only one vessel containing carbide of calcium be opened at one time, and then only for the time necessary for the removal of any required quantity of carbide, or for the refilling of the vessel.

(18) That vessels containing carbide of calcium be kept only in

____

____

____

(19) That fire, or any such artificial light as would ignite inflammable gas, be not taken into or near any building or place where carbide of calcium is kept.

(20) That the arrangements for the storage of petroleum and carbide of calcium, as approved by the Council and as seen by the Council's inspector last before the granting of this licence, be in all respects kept and maintained, unless the consent of the Council is given in writing to any departure therefrom.

(21) That every authorised officer of the Council be at all times allowed free access to the premises of the licensee, for the purpose of ascertaining if the above conditions are properly observed; and that the licensee do, by himself or his representatives, give any assistance for that purpose which such officer may require.

By Order of the Council,

____

Clerk of the Council.

SPRING GARDENS, S.W.

Section 9 of the Petroleum Act, 1871, provides that "any licensee violating any of the conditions of his licence shall be deemed to be an unlicensed person."

This licence is NOT transferable.

Received the sum of Five Shillings in respect of the above licence (Provisional Receipt No.).

£0 : 5 : 0

Countersigned,

Cashier.

for the Comptroller.

LONDON COUNTY COUNCIL.

F

Reg. No.

Petroleum Acts, 1871 to 1881, and Orders in Council as to Carbide of Calcium.

CARBIDE OF CALCIUM LICENCE.

PURSUANT to the provisions of the Petroleum Acts, 1871 to 1881, and of the Order in Council, dated February 26, 1897, the London County Council doth hereby at the request of ____________ ____ grant licence to ________________ for the period of twelve calendar months from the ____ to keep carbide of calcium on the premises ____________________ ____ in the parish of ____________________________ and within the jurisdiction of the said Council, subject to the conditions following, that is to say—

(1) That carbide of calcium which contains impurities liable to generate phosphoretted or siliciuretted hydrogen so as to render the gas evolved liable to ignite spontaneously, be not kept under this licence.

(2) That the total quantity of carbide of calcium kept on the premises at one time do not exceed ____________________________ ____

(3) That carbide of calcium be kept, sent or conveyed only in strong metal vessels, each of which shall be of a capacity not exceeding 3696 cubic inches, and be so constructed and closed as to prevent the admission of water or atmospheric moisture.

(4) That every vessel containing carbide of calcium shall bear a label stating in conspicuous characters the words, "Carbide of calcium," "Dangerous if not kept dry," and with the following caution—"The contents of this package are liable if brought into contact with moisture to give off a highly inflammable gas," and also the name and address of the owner or vendor in the case of carbide being kept, and the name and address of the sender when it is being conveyed.

(5) That only one vessel containing carbide of calcium be opened at one time, and then only for the time necessary for the removal of any required quantity of carbide, or for the refilling of the vessel.

(6) That vessels containing carbide of calcium be kept only in

____

____

____

(7) That fire, or any such artificial light as would ignite inflammable gas, be not taken into or near any building or place where carbide of calcium is kept.

(8) That the arrangements for the storage of carbide of calcium, as approved by the Council and as seen by the Council's inspector last before the granting of this licence, be in all respects kept and maintained, unless the consent of the Council is given in writing to any departure therefrom.

(9) That every authorised officer of the Council be at all times allowed free access to the premises of the licensee, for the purpose of ascertaining if the above conditions are properly observed; and that the licensee do, by himself or his representatives, give any assistance for that purpose which such officer may require.

By Order of the Council,

____

Clerk of the Council.

SPRING GARDENS, S.W.

Section 9 of the Petroleum Act, 1871, which applies to carbide of calcium, provides that any "licensee violating any of the conditions of his licence shall be deemed to be an unlicensed person."

This licence is NOT transferable.

Received the sum of Five Shillings in respect of the above licence (Provisional Receipt No.).

£0 : 5 : 0

Countersigned,

Cashier.

for the Comptroller.

LONDON COUNTY COUNCIL.

G

Reg. No.

Petroleum Acts, 1871 to 1881, and Orders in Council as to Carbide of Calcium.

CARBIDE OF CALCIUM LICENCE.

PURSUANT to the provisions of the Petroleum Acts, 1871 to 1881, and of the Order in Council, dated February 26, 1897, the London County Council doth hereby at the request of____________ ____ grant licence to__________________ for the period of twelve calendar months from the____ to keep carbide of calcium on the premises_________________________ ____ in the parish of____ and within the jurisdiction of the said Council, subject to the conditions following, that is to say—

(1) That carbide of calcium which contains impurities liable to generate phosphoretted or siliciuretted hydrogen so as to render the gas evolved liable to ignite spontaneously, be not kept under this licence.

(2) That the total quantity of carbide of calcium kept on the premises at one time do not exceed________________________________

(3) That carbide of calcium, except when being actually used in generating acetylene gas, be kept, sent or conveyed only in strong metal vessels, each of which shall be of a capacity not exceeding 3696 cubic inches, and be so constructed and closed as to prevent the admission of water or atmospheric moisture.

(4) That every vessel containing carbide of calcium shall bear a label stating in conspicuous characters the words, "Carbide of calcium," "Dangerous if not kept dry," and with the following caution—"The contents of this package are liable if brought into contact with moisture to give off a highly inflammable gas," and also the name and address of the owner or vendor in the case of carbide being kept, and the name and address of the sender when it is being conveyed.

(5) That only one vessel containing carbide of calcium be opened at one time, and then only for the time necessary for the removal of any required quantity of carbide or for the refilling of the vessel.

(6) That vessels containing carbide of calcium be kept only in

___

___

___

(7) That any quantity of carbide of calcium exceeding 2 lbs. in weight be only kept in a vessel or vessels securely locked, unless such vessel or vessels are in a locked receptacle.

(8) That fire, or any such artificial light as would ignite inflammable gas, be not taken into or near the building or place where carbide of calcium is kept or used in quantities exceeding 2 lbs.

(9) That any residue of carbide of calcium on being removed from a gas-making apparatus be at once mixed with at least ten times its bulk of water.

(10) That any apparatus containing carbide of calcium be only entrusted to the charge of a person properly instructed in its management.

(11) That the arrangements for the storage and use of carbide of calcium, as approved by the Council and as seen by the Council's inspector last before the granting of this licence, be in all respects kept and maintained, unless the consent of the Council is given in writing to any departure therefrom.

12) That every authorised officer of the Council be at all times allowed free access to the premises of the licensee, for the purpose of ascertaining if the above conditions are properly observed; and that the licensee do, by himself or his representatives, give any assistance for that purpose which such officer may require.

By Order of the Council,

___

Clerk of the Council.

SPRING GARDENS, S.W.

Section 9 of the Petroleum Act, 1871, which applies to carbide of calcium, provides that any "licensee violating any of the conditions of his licence shall be deemed to be an unlicensed person."

This Licence is NOT transferable.

Received the sum of Five Shillings in respect of the above licence (Provisional Receipt No.).

£0 : 5 : 0

Countersigned,

Cashier.

for the Comptroller.

APPENDIX VII.

Petroleum Act, 1879.

REGULATIONS AS TO CONSTRUCTION AND VERIFICATION OF APPARATUS FOR TESTING PETROLEUM.

FORM OF APPARATUS.

(1) Every apparatus should be a copy, in form as well as in materials, of the model deposited with this Board. The form and dimensions of such model are shown in Plate II., App. III.

(2) No greater deviation than two one-hundredths (0·02) of an inch should be made in the dimensions of the slide and the square holes on the cover of the oil cup. In other parts of the apparatus a deviation of one-tenth of an inch will be allowed.

THERMOMETERS.

(3) Thermometers should be carefully graduated, as shown on p. 262.

NAME-PLATE ON CERTAIN APPARATUS.

(4) Apparatus required for the use of any local authority under the Petroleum Acts should have the name of such local authority engraved on the front of the apparatus.

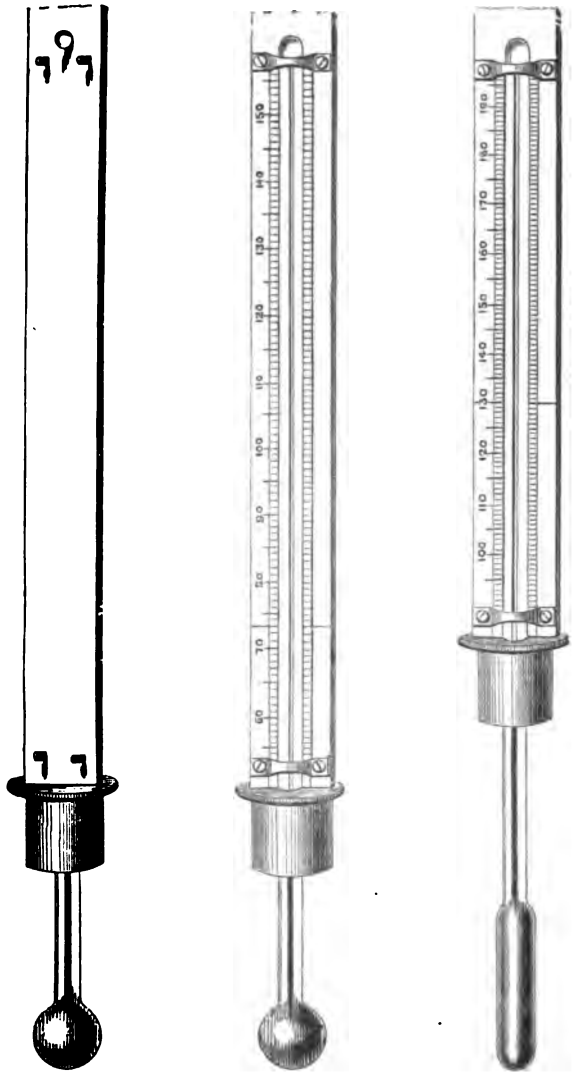
DELIVERY OF APPARATUS.

(5) Apparatus should be delivered at this office between 10 A.M. and 1 P.M. A written application or request should be sent with the apparatus, and when its comparison is completed due notice will be sent to the applicant.

Each apparatus should be packed in a deal, or mahogany, box.

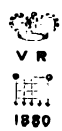
FEE OF VERIFICATION.

(6) On the verification of each apparatus a fee of five shillings will be charged.



Mark of Verification.

(7) The mark of verification approved by the Board of Trade and notified in the London Gazette is of the following design :



PENDULUM.

(8) A model of the lead line or pendulum used with this apparatus may be seen at this office.

BOARD OF TRADE,
Standards Office,
7, Old Palace Yard, Westminster,
January 1, 1880.

NOTE.—The blocks for the figures of the thermometers have been lent to us by the Controller of H.M. Stationery Office.

APPENDIX VIII.

TABLE FOR CORRECTION OF OBSERVED FLASHING-POINTS FOR VARIATIONS IN ATMOSPHERIC PRESSURE.

Barometer in inches.	27	27·2	27·4	27·6	27·8	28	28·2	28·4	28·6	28·8	29	29·2	29·4	29·6	29·8	30	30·2	30·4	30·6	30·8	[illegible]
Flashing point in Degrees Fahrenheit.	60·2	60·5	60·8	61·2	61·5	61·8	62·1	62·4	62·8	63·1	63·4	63·7	64	64·4	64·7	65	65·3	65·6	66	66·3	66·6
	61·2	61·5	61·8	62·2	62·5	62·8	63·1	63·4	63·8	64·1	64·4	64·7	65	65·4	65·7	66	66·3	66·6	67	67·3	67·6
	62·2	62·5	62·8	63·2	63·5	63·8	64·1	64·4	64·8	65·1	65·4	65·7	66	66·4	66·7	67	67·3	67·6	68	68·3	68·6
	63·2	63·5	63·8	64·2	64·5	64·8	65·1	65·4	65·8	66·1	66·4	66·7	67	67·4	67·7	68	68·3	68·6	69	69·3	69·6
	64·2	64·5	64·8	65·2	65·5	65·8	66·1	66·4	66·8	67·1	67·4	67·7	68	68·4	68·7	69	69·3	69·6	70	70·3	70·6
	65·2	65·5	65·8	66·2	66·5	66·8	67·1	67·4	67·8	68·1	68·4	68·7	69	69·4	69·7	70	70·3	70·6	71	71·3	71·6
	66·2	66·5	66·8	67·2	67·5	67·8	68·1	68·4	68·8	69·1	69·4	69·7	70	70·4	70·7	71	71·3	71·6	72	72·3	72·6
	67·2	67·5	67·8	68·2	68·5	68·8	69·1	69·4	69·8	70·1	70·4	70·7	71	71·4	71·7	72	72·3	72·6	73	73·3	73·6
	68·2	68·5	68·8	69·2	69·5	69·8	70·1	70·4	70·8	71·1	71·4	71·7	72	72·4	72·7	73	73·3	73·6	74	74·3	74·6
	69·2	69·5	69·8	70·2	70·5	70·8	71·1	71·4	71·8	72·1	72·4	72·7	73	73·4	73·7	74	74·3	74·6	75	75·3	75·6
	70·2	70·5	70·8	71·2	71·5	71·8	72·1	72·4	72·8	73·1	73·4	73·7	74	74·4	74·7	75	75·3	75·6	76	76·3	76·6
	71·2	71·5	71·8	72·2	72·5	72·8	73·1	73·4	73·8	74·1	74·4	74·7	75	75·4	75·7	76	76·3	76·6	77	77·3	77·6
	72·2	72·5	72·8	73·2	73·5	73·8	74·1	74·4	74·8	75·1	75·4	75·7	76	76·4	76·7	77	77·3	77·6	78	78·3	78·6
	73·2	73·5	73·8	74·2	74·5	74·8	75·1	75·4	75·8	76·1	76·4	76·7	77	77·4	77·7	78	78·3	78·6	79	79·3	79·6
	74·2	74·5	74·8	75·2	75·5	75·8	76·1	76·4	76·8	77·1	77·4	77 7	78	78·4	78·7	79	79·3	79·6	80	80·3	80·6
	75·2	75·5	75·8	76·2	76·5	76·8	77·1	77·4	77·8	78·1	78·4	78·7	79	79·4	79·7	80	80·3	80·6	81	81·3	81·6

APPENDIX IX.

STATUTORY RULES AND ORDERS, 1900.
No. 303.

LOCOMOTIVE.
Petroleum.

REGULATIONS DATED APRIL 26, 1900, MADE BY THE SECRETARY OF STATE UNDER SECTION 5 OF THE LOCOMOTIVES ON HIGHWAYS ACT, 1896, AS TO THE KEEPING AND USE OF PETROLEUM FOR THE PURPOSES OF LIGHT LOCOMOTIVES.

Locomotives on Highways Act, 1896.
(59 & 60 Vict. c. 36, s. 5.)

In promulgating the following Regulations relating to the keeping, conveyance and use of petroleum in connection with light locomotives, the Secretary of State for the Home Department desires to direct public attention to the dangers that may arise from the careless use of the more volatile descriptions of petroleum, commonly known as petroleum spirit. Not only is the vapour therefrom, which is given off at ordinary temperatures, capable of being easily ignited, but it is also capable, when mixed with air, of forming an explosive atmosphere. It is, therefore, necessary in dealing with and handling the spirit, to take strict precautions by the employment of thoroughly sound and properly closed vessels, and by avoiding the use of naked lights in dangerous proximity, to prevent leakage of the spirit and the contact of any form of artificial light with the highly inflammable vapour which it is always evolving.

REGULATIONS.

By virtue of the powers conferred on me by the Fifth Section of the Locomotives on Highways Act, 1896, I hereby make the following Regulations for the keeping and use of petroleum for the purposes of light locomotives.

Save as herein provided the provisions of the Petroleum Acts shall apply to all petroleum kept or used or sold for the purposes of light locomotives.

In these regulations the expression "petroleum spirit" shall mean the petroleum to which the Petroleum Act, 1871, applies, provided that when any petroleum other than that to which the Petroleum Act, 1871, applies is on or in any light locomotive, or is being conveyed or kept in any place on or in which there is also present any petroleum spirit as above defined, the whole of such petroleum shall be deemed to be petroleum spirit.

In these regulations the expression "storehouse" shall mean any room, building, coachhouse, lean-to, or other place in which petroleum spirit for the purposes of light locomotives is kept in pursuance of these regulations.

(1) These regulations shall apply only to petroleum spirit which is kept for the purpose of or is being used on light locomotives, and shall not apply to petroleum spirit which is kept for sale, or partly for sale and partly for the purposes of light locomotives.

(2) Petroleum spirit should not be kept, used, or conveyed except in metal vessels so substantially constructed as not to be liable, except under circumstances of gross negligence or extraordinary accident, to be broken or become defective or insecure. Every such vessel shall be so constructed and maintained that no leakage, whether of liquid or vapour, can take place therefrom.

(3) Every such vessel, not forming part of a light locomotive, when used for conveying or keeping petroleum spirit shall bear the words "petroleum spirit highly inflammable" legibly and indelibly stamped or marked thereon, or on a metallic or enamelled label attached thereto, and shall be of a capacity not exceeding two gallons.

(4) Before repairs are done to any such vessel, that vessel shall, as far as practicable, be cleaned by the removal of all petroleum spirit and of all dangerous vapours derived from the same.

(5) Where a storehouse forms part of, or is attached to, another building, and where the intervening floor or partition is of an unsubstantial or highly inflammable character, or has an opening therein, the whole of such building shall be deemed to be the storehouse, and no portion of such storehouse shall be used as a dwelling or as a place where persons assemble. A storehouse shall have a separate entrance from the open air distinct from that of any dwelling or building in which persons assemble.

(6) Every storehouse shall be thoroughly ventilated.

(7) The amount of petroleum spirit to be kept in any one storehouse, whether or not upon light locomotives, shall not exceed 60 gallons at any one time.

(8) Where two or more storehouses are in the same occupation and are situated within 20 feet of one another, they shall for the

purposes of these regulations be deemed to be one and the same storehouse, and the maximum amount of petroleum spirit prescribed in the foregoing regulation shall be the maximum to be kept in all such storehouses taken together. Where two or more storehouses in the same occupation are distant more than 20 feet from one another, the maximum amount shall apply to each storehouse.

(9) Any person who keeps petroleum spirit in a storehouse which is situated within 20 feet of any other building whether or not in his occupation, or of any timber stack or other inflammable goods not owned by him, shall give notice to the local authority under the Petroleum Acts for the district in which he is keeping such petroleum spirit, that he is so keeping petroleum spirit, and shall renew such notice in the month of January in each year during the continuance of such keeping, and shall permit any duly authorised officer of the local authority to inspect such petroleum spirit at any reasonable time. This regulation shall not apply to petroleum spirit kept under licence, nor to petroleum spirit kept in a tank forming part of a light locomotive.

(10) The filling or replenishing of a vessel with petroleum spirit shall not be carried on, nor shall the contents of any such vessel be exposed in the presence of fire or artificial light, except a light of such construction, position or character, as not to be liable to ignite any inflammable vapour arising from such spirit, and no artificial light shall be brought within dangerous proximity of the place where any vessel containing petroleum spirit is being kept.

(11) In the case of all petroleum spirit kept or conveyed for the purpose of or in connection with any light locomotive, (*a*) all due precautions shall be taken for the prevention of accidents by fire or explosion, and for the prevention of unauthorised persons having access to any petroleum spirit kept or conveyed, and to the vessels containing or intended to contain, or having actually contained the same; and (*b*) every person managing or employed on or in connection with any light locomotive shall abstain from every act whatever which tends to cause fire or explosion, and which is not reasonably necessary, and shall prevent any other person from committing such act.

(12) These regulations shall come into operation on the 15th day of May, 1900, from which date the regulations dated 3rd November, 1896, are hereby repealed.

M. W. RIDLEY,

One of Her Majesty's Principal Secretaries of State.

Whitehall, S.W., *26th April*, 1900.

APPENDIX X.

SPECIFICATIONS OF TANK DEPOTS AND SCREEN WALLS.

(Proposed to be included in an Act of Parliament.)

General.

Any tank which satisfies the following conditions shall be deemed to be a tank depôt for the purposes of this Act:

(1) It must be constructed of good metal.

(2) It must be properly tested before use, and seen to be perfectly tight and staunch.

(3) It must at all times while in use be so well fitted that the inflammable liquid contained in it cannot escape therefrom in the form of liquid, whether under the action of fire or otherwise.

(4) If it has a ventilating pipe, that pipe must be of suitable character and construction, and its orifice must be effectively protected by wire gauze.

(5) Every other opening in the tank, whether to be used as a manhole or for a pipe or other purpose, not being such a ventilating pipe as aforesaid, must have a neck whose length is at least equal to one-half of the diameter of the opening, and every such opening, when not in actual use, must be securely closed by an effective and properly secured cap, cover or tap.

(6) It must be further constructed as hereunder specified according as it is an underground or overground tank—that is to say:

I. Underground Tanks.

A tank shall be deemed to be an underground tank which is wholly sunk in and surrounded by solid rock or earth, and the top of which is protected by a substantial covering of not less than nine inches of solid earth, sand, or concrete. There must be no opening in such top or covering, other than such manholes, pipes, pumps, or other connections as may be necessary.

Every underground tank must be constructed of strong iron or steel tank-plates well riveted together and thoroughly caulked. The tops and sides must be supported and strengthened by such

uprights, girders, angle-irons, and ties as, having regard to the capacity and situation of the tank, may be necessary to render the tank thoroughly substantial and effective.

The underground space in which the tank is enclosed must be of such construction and character that mineral oil cannot escape therefrom in the form of liquid, whether under the action of fire or otherwise, so as to reach either directly or indirectly any other place where inflammable liquid is kept, or any protected work,* or any river, sewer, stream or drain.

II. Overground Tanks.

Every tank shall be deemed to be an overground tank which in respect of situation does not satisfy the conditions hereinbefore specified for an underground tank.

If the tank is to be placed or fixed elsewhere in a building than on the basement, its position must be approved by the local authority.

(*a*) Every tank of a capacity not exceeding 60 gallons must be well constructed of galvanised iron of such strength, having regard to its size, and with seams so securely closed and fastened, as to form an effective receptacle for the inflammable liquid which it contains.

(*b*) Every tank of a capacity exceeding 60 but not exceeding 1000 gallons must be constructed of good galvanised iron plates of such thickness, and with rivets of such size, and at such distances apart (measured from centre to centre) as appear in the following scale:

For tanks of a capacity not exceeding	Thickness of plates not less than	Size of rivets not less than	Distance of rivets apart not more than
100 Gallons	$\frac{1}{16}$ inch	$\frac{1}{4}$ inch	$\frac{3}{4}$ inch
250 "	$\frac{1}{8}$ inch	$\frac{3}{8}$ "	$1\frac{1}{8}$ "
500 "	$\frac{1}{8}$ inch	$\frac{3}{8}$ "	$1\frac{1}{8}$ "
1000 "	$\frac{3}{16}$ inch if cylindrical $\frac{1}{4}$ inch if any other shape	$\frac{7}{16}$ "	$1\frac{1}{4}$ "

If the tank has a capacity exceeding 60 but not exceeding 250 gallons, it must rest on the ground, or on brick or stone piers, or must be securely and adequately supported on strong girders.

If the tank has a capacity exceeding 250 but not exceeding 1000

* For definition of Protected Work *see* p. 164.

gallons, it must be properly stiffened with vertical angle-irons and cross-stays, and must rest on solid foundations of concrete, brick, or stone.

(c) Every tank of a capacity exceeding 1000 gallons must be cylindrical in shape, and must not exceed 26 feet in height or 35 feet in diameter. The top of the tank must be constructed of plates of a thickness of $\frac{1}{8}$ inch, riveted with $\frac{3}{8}$ inch rivets, not more than $1\frac{1}{8}$ inch apart, and supported by a sufficient number of strong and efficient angle-irons and ties, and where necessary by king posts.

The sides and bottom of the tank must be of best iron or steel tank plates of at least the following thicknesses:

Namely,	within 10 feet from the top of the tank	$\frac{1}{4}$	inch thick.
„	over 10 and within 20 feet from the top of the tank	$\frac{5}{16}$	„
„	over 20 feet from the top of the tank	$\frac{3}{8}$	„
„	bottom of tank	$\frac{1}{4}$	„

The plates must be riveted by $\frac{3}{8}$ inch best rivets driven hot, and not more than $1\frac{7}{8}$ inch apart measured from centre to centre, and all vertical seams must be double riveted.

Every such tank must be erected on good solid foundations, upon which the entire bottom surface shall have a fair bearing, and must be strengthened throughout by a sufficient number of strong and efficient angle-irons and cross-stays.

If the tank has a capacity of more than 15,000 gallons, it must be constructed as hereinbefore described, and further, must be separately surrounded by a wall of such dimensions and substantial construction, or must be partially sunk in an excavation in such a manner that the total quantity of mineral oil capable of being contained in the tank could be altogether contained in the enclosure formed by such wall or excavation, and could not escape therefrom in the form of liquid, whether under the action of fire or otherwise; and the space formed by such wall or excavation, so far as not occupied by the tank, must be kept entirely free and unoccupied.

Specification of Screen Wall.

A screen wall must be substantially constructed of good hard bricks, or such good building stone, not being limestone, or such concrete as may be approved by the local authority, properly bonded, and solidly put together with good mortar or cement, on proper footings and foundations.

A screen wall must be of a thickness of not less than as follows:

Within 16 feet of the top of the wall, 13 inches.
Over 16 feet, and within 32 feet of the top of the wall, 17½ inches.
,, 32 ,, ,, 48 ,, ,, ,, ,, 22 ,,

and in like proportion for any greater height.

A screen wall must be strengthened by two or more transverse buttresses of similar construction to the wall. The buttresses must be carried up to the top of the wall and properly bonded thereto, and must not be more than 20 feet distant from each other. Each buttress must, at its base, project from each side of the wall not less than one-eighth the height of the wall, and at its top not less than nine inches. There must be no window, door, or other opening in a screen wall, other than such fire-proof doors as are necessary for the purposes of access to the premises, and are open only when required for the said purposes.

APPENDIX XI.

SUGGESTIONS FOR THE CARE AND USE OF PETROLEUM LAMPS.

(1) The wick should quite fill the wick-tube, without having to be squeezed into it.

(2) Before using, the wick should be dried at the fire, and then immediately soaked with oil.

(3) Wicks should be in lengths of not more than 10 inches, and should always reach to the bottom of the oil container.

(4) It is well to change the wick after two months' use.

(5) See that the chimney of the lamp fits properly and is held sufficiently tightly so as not to fall off when the lamp is used.

(6) When a new wick or chimney is required, it is always advisable to take the burner to the shop that it may be properly fitted.

(7) The burner should be taken to pieces and thoroughly cleansed at least once a month, and all burnt pieces of wick, dead flies, dirt, &c., should be carefully removed.

(8) Never refill the lamp when it is alight, or near a fire or other light.

(9) After filling see that the burner is properly fixed on, and if there is a side filling-hole, be careful to screw in the plug.

(10) Before lighting remove the burnt crust of the wick.

(11) Be careful not to spill oil in filling, and if any is spilt on the lamp, to wipe it off.

(12) Before lighting see that the slit in the cone of the burner is exactly in line with the wick-tube, so that the flame will not touch the metal.

(13) When first lit, the wick should be partially turned down, and then gradually raised but not so as to smoke. When the edge of the flame is orange-coloured the lamp is not burning properly, and the burner should be examined.

(14) Do not continue to burn the oil until it is completely exhausted. It is best to keep the lamp well filled.

(15) Lamps which have no extinguisher should be put out as follows: The wick should be turned down until there is only a small flickering flame, care being taken not to turn down so far that the wick falls into the oil container. The small flame may be extinguished by placing a piece of flat tin or card on the top of the chimney, or by blowing across the top of the chimney. Never blow down the chimney.

(16) Never use a lamp which is broken or in any way out of order, or a chimney which is cracked. If any part comes loose, or is out of shape or defective, it should be taken to a lamp shop to be repaired.

(17) Always place the lamp in a secure place and on a level surface, and never on a rickety table or in any position where it could be easily upset. Hanging lamps should not be put on insecure nails in the wall.

(18) Table lamps should not be carried about more than is necessary, and nothing else should be carried at the same time. Heavy lamps should be carried in both hands. The greater number of accidents have been caused by dropping a lamp while it was being carried.

(19) Lamps should not be turned down except for the purpose of putting them out. If turned low the oil is apt to be unduly heated.

(20) Should a person's clothes become ignited, the flames should be smothered with a hearthrug, blanket, woollen table cloth, or wet towel.

(21) NEVER POUR OIL ON A FIRE.

APPENDIX XII.

Petroleum Act, 1871.

CARBIDE OF CALCIUM.

ORDER IN COUNCIL OF FEBRUARY 26, 1897; PUBLISHED IN THE "LONDON GAZETTE" OF MARCH 2, 1897.

At the Court at Windsor, the 26th day of February, 1897.

PRESENT:

The Queen's Most Excellent Majesty in Council.

WHEREAS it is provided by the Petroleum Act, 1871, that Her Majesty may, from time to time, make, revoke, and vary Orders in Council directing that the said Act or any part thereof shall apply to any substance, and that the said Act or the part thereof specified in any such Order shall, during the continuance of the Order, apply to such substance, and shall be construed and have effect as if such substance had been included in the definition of petroleum to which that Act applies, subject to the following qualifications:

(1) The quantity of any substance to which this Act is directed by Order in Council to apply which may be kept without a licence, shall be such quantity only as is specified in that behalf in such order, or if no such quantity is specified no quantity may be kept without a licence.

(2) The label on the vessel containing such substance shall be such as may be specified in that behalf in the Order.

And whereas the Petroleum Act, 1879, and the Petroleum (Hawkers) Act, 1881, are to be construed as one with the Petroleum Act of 1871, and may, together with such Act, be cited as the Petroleum Acts, 1871 to 1881:

And whereas carbide of calcium presents dangers similar to those presented by petroleum:

Now, therefore, in pursuance of the above-mentioned provisions of the Petroleum Act, 1871, Her Majesty is pleased, by and with the advice of Her Privy Council, to order and prescribe that the under-mentioned parts of the Petroleum Acts, 1871 to 1881, shall

apply to the said substance, carbide of calcium, in the same manner as if the said substance were petroleum to which the Acts apply, viz.:

The whole of the Petroleum Acts, 1871 to 1881, except:

(*a*) So much of Section 6 of the Petroleum Act, 1871, as specifies the nature of the label to be on the vessel, in lieu of which the label shall be as hereinafter provided.

(*b*) So much of Section 7 of the Petroleum Act, 1871, as relates to the exemption from such section of small quantities under certain specified conditions, and no quantity of carbide of calcium may be kept except in pursuance of such licence as in the said Section 7 is provided.

(*c*) So much of Section 11 of the Petroleum Act, 1871, as relates to the testing of samples taken by an officer of the local authority under the powers conferred by such section.

(*d*) So much of the Petroleum Act, 1879, as relates to the testing of petroleum.

(*e*) So much of the Petroleum Act, 1881, as relates to the hawking of petroleum.

The label on the vessel containing the said carbide of calcium shall bear in conspicuous characters the words "Carbide of calcium," "Dangerous if not kept dry," and with the following caution: "The contents of this package are liable if brought into contact with moisture to give off a highly inflammable gas," and with the addition:

(*a*) In the case of a vessel kept, of the name and address of the consignee or owner.

(*b*) In the case of a vessel sent or conveyed, of the name and address of the sender.

(*c*) In the case of a vessel sold or exposed for sale, of the name and address of the vendor.

This Order shall come into effect on the 1st of April, 1897.

C. L. PEEL.

STATUTORY RULES AND ORDERS, 1897.
No. 544.

PETROLEUM.
Carbide of Calcium.

ORDER IN COUNCIL AMENDING THE ORDER IN COUNCIL OF FEBRUARY 26, 1897,* DIRECTING THAT CERTAIN PORTIONS OF THE PETROLEUM ACTS, 1871 TO 1881, SHALL APPLY TO CARBIDE OF CALCIUM.†

At the Court at Windsor, the 7th day of July, 1897.

PRESENT:

The Queen's Most Excellent Majesty in Council.

WHEREAS it is expedient to exempt small quantities of carbide of calcium, when kept under certain conditions, from the operation of the Order in Council of the 26th February, 1897, in virtue of which certain parts of the Petroleum Acts, 1871 to 1881, are applied to carbide of calcium in the same manner as if the said substance were petroleum, to which the Act applies:

Now, therefore, Her Majesty is pleased, by and with the advice of Her Privy Council, to order and prescribe that notwithstanding anything to the contrary in the said Order in Council, the quantity of carbide of calcium which may be kept without a licence shall be as follows:

(*a*) Where it is kept in separate substantial hermetically closed metal vessels containing not more than 1 lb. each . . . . 5 lbs.

(*b*) Where it is kept otherwise . . . . . . None;

and the said Order in Council shall be deemed to be amended accordingly.

C. L. PEEL.

* Statutory Rule and Order, 1897, No. 171.

† This Order was published in the London Gazette of July 9, 1897.

APPENDIX XIII.

Petroleum Act, 1871.

(34 & 35 Vict. c. 105.)

SUGGESTED MODEL CODE OF HARBOUR BY-LAWS RELATING TO CARBIDE OF CALCIUM.

(1) THE owner or master of every ship carrying a cargo, any part of which consists of carbide of calcium, shall, on entering the harbour, immediately give notice of the nature of such cargo to the harbour-master, and shall place or moor his ship in such place as the harbour-master may direct; and while any carbide of calcium remains on board shall not, except for the purpose of proceeding to sea, remove his ship without the written permission of the harbour-master.

(2) The hold of every ship carrying carbide of calcium shall be efficiently ventilated from the time of entering the harbour until all the carbide of calcium has been discharged or until the ship has left the harbour.

(3) All carbide of calcium landed from any ship shall be removed without unnecessary delay to some duly licensed place of storage or beyond the limits of the jurisdiction of the harbour authority.

(4) Carbide of calcium shall only be brought into the harbour in hermetically closed metal vessels containing each not more than 140 lbs., and of such strength and construction as not to be liable to be broken or to become defective or insecure in conveyance otherwise than by gross negligence or extraordinary accident.

(5) No vessel containing carbide of calcium shall be opened within the limits of the jurisdiction of the harbour authority except in some licensed place of storage or with the written consent of the harbour-master.

(6) Every reasonable precaution shall be taken to prevent the contact of water or moisture with the carbide of calcium, and where such contact may have occurred, to prevent the gas evolved from being ignited.

(7) The names and expressions used in the foregoing by-laws hall have the same meaning as is assigned to the same names and expressions in the Petroleum Act, 1871.

APPENDIX XIV.

ORDER IN COUNCIL No. 17.

Explosives Act, 1875.

(38 Vict. c. 17.)

ORDER IN COUNCIL RELATING TO ACETYLENE GAS.

At the Court at Windsor, the 26th day of November, 1897.

PRESENT:

The Queen's Most Excellent Majesty in Council.

WHEREAS by section one hundred and four of the Explosives Act, 1875, it is enacted that Her Majesty may, by Order in Council, declare that any substance which appears to Her Majesty to be specially dangerous to life or property by reason either of its explosive properties, or of any process in the manufacture thereof being liable to explosion, shall be deemed to be an explosive within the meaning of the said Act, and the provisions of the said Act (subject to such exceptions, limitations, and restrictions as may be specified in the Order) shall accordingly extend to any such substance in like manner as if it were included in the term explosive in the said Act:

And whereas acetylene when liquid or subject to a certain degree of compression is specially dangerous to life or property by reason of its explosive properties:

Now, therefore, Her Majesty is pleased by and with the advice of Her Privy Council to order and declare, and be it ordered and declared as follows:

Acetylene when liquid or when subject to a pressure above that of the atmosphere capable of supporting a column of water exceeding one hundred inches in height and whether or not in admixture with other substances, shall be deemed to be an explosive within the meaning of the said Act, subject to the following exception; that if it be shown to the satisfaction of the Secretary of State that acetylene, declared to be explosive by this Order when in admixture with any substance, or in any

form or condition, is not possessed of explosive properties, the Secretary of State may by Order exempt such acetylene from being deemed to be an explosive within the said Act.

And whereas by section forty-three of the Explosives Act, 1875, it is provided that Her Majesty from time to time by Order in Council, may prohibit, either absolutely or except in pursuance of a licence of the Secretary of State under the said Act, or may subject to conditions or restrictions the manufacture, keeping, importation from any place out of the United Kingdom, conveyance, and sale, or any of them, of any explosive which is of so dangerous a character that in the judgment of Her Majesty it is expedient for the public safety to make such Order:

And whereas it is in the judgment of Her Majesty expedient for the public safety that acetylene, when an explosive within the meaning of this Order, shall be prohibited:

Now, therefore, in pursuance of the above-mentioned provision of this Act, Her Majesty is pleased, by and with the advice of Her Privy Council, to order and prescribe that acetylene declared to be an explosive by this Order shall be prohibited from being manufactured, imported, kept, conveyed, or sold.

C. L. PEEL.

ORDER IN COUNCIL No. 18.

STATUTORY RULES AND ORDERS, 1900.
No. 345.

EXPLOSIVE SUBSTANCE.

Order in Council Prohibiting the Manufacture, Importation, Keeping, Conveying or Sale of Acetylene when an Explosive as defined by the Order.

At the Court at Windsor, the 15th day of May, 1900.

Present:

The Queen's Most Excellent Majesty in Council.

Whereas by section one hundred and four of the Explosives Act, 1875, it is enacted that Her Majesty may, by Order in Council, declare that any substance which appears to Her Majesty to be specially dangerous to life or property by reason either of its explosive properties, or of any process in the manufacture thereof being liable to explosion, shall be deemed to be an explosive within

the meaning of the said Act, and the provisions of the said Act (subject to such exceptions, limitations, and restrictions as may be specified in the Order) shall accordingly extend to any such substance in like manner as if it were included in the term explosive in the said Act:

And whereas acetylene when in admixture with air or oxygen is specially dangerous to life or property by reason of its explosive properties:

And whereas the provisions of section one of The Rules Publication Act, 1893, have been complied with:

Now, therefore, Her Majesty is pleased by and with the advice of Her Privy Council to order and declare and be it ordered and declared as follows:

Acetylene when in admixture with atmospheric air or with oxygen gas in whatever proportion and at whatever pressure and whether or not in admixture with other substances shall be deemed to be an explosive within the meaning of the said Act.

And whereas by section forty-three of the Explosives Act, 1875, it is provided that Her Majesty, from time to time by Order in Council, may prohibit, either absolutely or except in pursuance of a licence of the Secretary of State under the said Act, or may subject to conditions or restrictions the manufacture, keeping, importation from any place out of the United Kingdom, conveyance, and sale or any of them, of any explosive which is of so dangerous a character, that in the judgment of Her Majesty it is expedient for the public safety to make such Order:

And whereas it is in the judgment of Her Majesty expedient for the public safety that acetylene in admixture with air or oxygen, when an explosive within the meaning of this Order, shall be prohibited:

Now, therefore, Her Majesty is pleased, by and with the advice of Her Privy Council, to order and prescribe that acetylene in admixture with air or oxygen, declared to be an explosive by this Order, shall be prohibited from being manufactured, imported, kept, conveyed, or sold.

Provided that nothing in this Order shall apply to acetylene in admixture with air when such admixture takes place only in a burner or contrivance in which the mixture is intended to be burnt.

Provided also that nothing in this Order shall be held to apply to an admixture of acetylene and air which may unavoidably occur in the first use or re-charging of an apparatus, properly designed and constructed with a view to the production of pure acetylene.

A. W. FITZROY.

STATUTORY RULES AND ORDERS, 1898.
No. 248.

EXPLOSIVE SUBSTANCE.

ORDER OF SECRETARY OF STATE (No. 5), DATED MARCH 28, 1898, RELATING TO COMPRESSED ACETYLENE IN ADMIXTURE WITH OIL-GAS.

Explosives Act, 1875.

(38 Vict. c. 17.)

WHEREAS by an Order in Council, dated November 26, 1897, made under section 104 of the Explosives Act, 1875, it is declared that acetylene when liquid, or when subject to a certain degree of compression, shall be deemed to be an explosive within the meaning of the said Act:

And whereas by the said Order in Council it is provided that if it be shown to the satisfaction of the Secretary of State that acetylene, declared to be an explosive by the said Order when in admixture with any substance, or in any form or condition, is not possessed of explosive properties, the Secretary of State may by Order exempt such acetylene from being deemed to be an explosive within the meaning of the said Act:

And whereas it has been shown to the satisfaction of the Secretary of State that acetylene, when in admixture with a gas manufactured from mineral oil (hereinafter referred to as oil-gas) in certain proportions, and not compressed beyond a certain pressure, is not possessed of explosive properties:

Now, therefore, in exercise of the powers aforesaid, I, one of Her Majesty's Principal Secretaries of State, hereby order as follows:

Acetylene in admixture with oil-gas in a proportion not exceeding twenty parts by volume of acetylene in every one hundred parts of the mixture, when subjected to a pressure not exceeding one hundred and fifty pounds to the square inch, shall not be deemed to be an explosive within the meaning of the said Act.

Provided that the acetylene and oil-gas shall be mixed together in a chamber or vessel before the gases are subjected to compression.

M. W. RIDLEY.

WHITEHALL,
March 28, 1898.

STATUTORY RULES AND ORDERS, 1901.

No. 310.

EXPLOSIVE SUBSTANCE.

ORDER OF SECRETARY OF STATE (No. 6), DATED APRIL, 10, 1901, RELATING TO ACETYLENE COMPRESSED INTO POROUS SUBSTANCES WITH AND WITHOUT ACETONE.

Explosives Act, 1875.

(38 Vict. c. 17.)

WHEREAS by an Order in Council dated 26th November, 1897, made under Section 104 of the Explosives Act, 1875, it is declared that acetylene when liquid or when subject to a certain degree of compression, shall be deemed to be an explosive within the meaning of the said Act.

And whereas by the said Order in Council it is provided that if it be shown to the satisfaction of the Secretary of State that acetylene, declared to be an explosive by the said Order, when in admixture with any substance, or in any form or condition, is not possessed of explosive properties, the Secretary of State may, by Order, exempt such acetylene from being deemed to be an explosive within the meaning of the said Act.

And whereas it has been shown to the satisfaction of the Secretary of State that acetylene, when compressed into a certain porous substance, and into a certain other porous substance containing acetone, is not possessed of explosive properties.

Now, therefore, in exercise of the powers aforesaid, I, being one of His Majesty's Principal Secretaries of State, hereby order as follows:—

Subject to the conditions hereinafter specified, acetylene when compressed into porous substances, with or without acetone shall not be deemed to be an explosive within the meaning of the said Act, provided that:—

(1) The porous substances to be used, with or without acetone, shall be similar in every respect to samples deposited at the Home Office.

(2) The porous substance shall fill, as completely as possible, the cylinder or other vessel into which the acetylene is compressed.

(3) The porosity of the substance shall not exceed eighty per cent.

(4) Due precaution shall be taken to exclude air from every part of the apparatus before the acetylene is compressed.

(5) Due precaution shall be taken to prevent undue rise of temperature in compressing the acetylene.

(6) The pressure shall not exceed one hundred and fifty pounds to the square inch.

(7) Every cylinder or other vessel into which acetylene is to be compressed shall be tested by hydraulic pressure of not less than double the pressure to which the vessel is to be submitted into use, such hydraulic pressure being maintained for a period of not less than ten minutes.

(8) In the case where acetone is used for absorbing the acetylene, due precaution shall be taken that the quantity of acetone is such that when fully charged with acetylene it does not completely fill the porosity of the porous substance.

(9) The compression of the acetylene shall be carried out only on such premises as shall have been approved in writing by one of His Majesty's Inspectors of Explosives.

(10) Every cylinder or other vessel in which acetylene has been compressed in virtue of this Order shall be legibly marked with the words—

"Acetylene compressed into porous substance exempted by Order of Secretary of State dated 10th April, 1901,"

together with the name of the firm by whom the vessel has been charged.

(11) Every facility shall be given to His Majesty's Inspectors of Explosives to inspect the apparatus and methods by which the cylinders or other vessels are charged in virtue of this Order.

CHAS. T. RITCHIE.

WHITEHALL,
April 10, 1901.

APPENDIX XV.

LONDON COUNTY COUNCIL.

Report as to licensed premises in the County of London, upon which petroleum, under the Acts, is used in trade or manufacture.

Presented to the Sanitary and Special Purposes Committee, November 14, 1890.

Petroleum Acts.

In accordance with the instructions of the committee at their meeting on October 31, that I should prepare a report submitting a list of the businesses carried on in London in which petroleum spirit is used in manufacturing processes or otherwise, I have to report as follows:

The following is a list of the businesses, in which petroleum is so used, carried on in the county of London under the licences of the Council:

Dry Cleaners (21 licensed premises).
Helmet Manufacturers (5 licensed premises).
Tennis Shoe Manufacturers (4 licensed premises).
Indiarubber Manufacturers (12 licensed premises).
Waterproof Garment Manufacturers (41 licensed premises).
Glass Silverers (14 licensed premises).
Paint Manufacturers (6 licensed premises).
Glove Cleaners (41 licensed premises).

The licences granted in respect of all these businesses have special conditions attached, with a view to safety, and in some cases these conditions appear to be fully adequate, as they probably reduce the danger in the particular processes carried on to the minimum. In some of the businesses, however, it may be desirable to make some addition to the existing precautions.

Whenever mineral spirit or its inflammable vapour is liable to be present in workrooms in dangerous quantity, the following precautions should, wherever possible, be adopted :

(*a*) The workroom should be a detached fire-proof building on a level with the ground.

(*b*) The workroom should be well ventilated, both at the ground and ceiling levels.

(*c*) The workroom should be provided with doors opening outwards, in order to facilitate the escape of the workpeople in case of accident.

(*d*) The process in which mineral spirit is used should be carried on in closed vessels, and where that is not possible, the exposure of spirit should be reduced to a minimum, in order to lessen the formation of inflammable vapour.

(*e*) Such artificial light as would ignite inflammable vapour should be wholly excluded from workrooms in which mineral spirit is used. The only artificial light allowed should be incandescent electric light, or a form of gas light where the light is so enclosed as not to be in contact with the air of the workroom.

Taking the businesses in the order in which they appear in the above list, the first to be dealt with is—

(1) *Dry Cleaners.*—In this business mineral spirit is used, generally in large quantity, in the cleaning of dress material and other substances. The spirit is kept in specially constructed stores, and the cleaning takes place in specially constructed buildings.

Practically all the conditions for safety already indicated are insisted on by the conditions attached to licences granted to dry cleaners in London.

Formerly there were numerous accidents in connection with this business, but for the past few years, since the adoption of the indicated precautions, only one fire has occurred in London; and fortunately, on account of the isolation of the building and the precautions imposed by the licence, no fatality or even personal injury resulted, nor did the fire extend beyond the actual building in which it broke out. It may be mentioned as an instance of the value of precautions in businesses of this nature, that on one of the dry cleaner's premises, before the present stringent conditions were insisted upon, the cleaning room was burnt out five times in six years; but that since the adoption of these precautions some seven years since, no fire has occurred on the premises.

(2) *Helmet Manufacturers.*—In this business a quantity of petroleum spirit, in no case exceeding 45 gallons, is used for the purpose of dissolving indiarubber, to form a solution used in cementing and waterproofing some forms of helmets. I do not consider the conditions attached to licences for premises in which this business is carried on are sufficiently stringent. Difficulty was experienced in obtaining adequate arrangements for safety, both on account of the

situation and construction of many of the premises. In every case, however, the petroleum spirit is kept, and the indiarubber solution is made, in a store which is as far as possible detached from the work-rooms. The solution is used for cementing and waterproofing helmets, and in the room in which this is done, as well as in the place in which the helmets are afterwards dried, a considerable amount of inflammable vapour is given off. This vapour is to some extent carried off by ventilation, but at present artificial light is used in some of the workrooms; and, looking to the recent fatal accident at a helmet manufacturer's in Cloth Fair, I think that such a method of lighting should no longer be permitted. No special provision is made upon any of the licensed helmet-makers' premises for the escape of workpeople in case of accident, and the Committee may consider it desirable in future to license only premises where adequate means of escape have been provided. I may, however, point out that no serious fire, or any fire involving loss of life, has occurred in recent years upon any of the licensed premises. The recent fatal fire on Messrs. Rowley and Brock's premises (which are in the city and under the jurisdiction of the Corporation of London) probably arose from the very grossest carelessness and the neglect of the most elementary precautions. An uncorked can containing a solution of naphtha and indiarubber was placed in the drying-stove, and on the door of the stove being opened a volume of the vapour escaped and ignited.

Although no accident can be traced to the use of naked lights in workrooms where solution is used, it would undoubtedly reduce the danger if the Council insisted on the abolition of such lights and the substitution of the incandescent electric light or some perfectly safe form of gas lighting. In every case where a drying stove by fire heat is used, such stove should unquestionably be separated from the workrooms and ventilated into the external air, or in other words it should be a distinct fire risk.

(3) *Tennis Shoe Makers.*—In this trade an indiarubber solution is used for cementing indiarubber soles to the uppers. The danger and the conditions are very similar to those in the case of helmet-makers, and whatever the Committee decide as to the one trade should be applied to the other.

(4) *Indiarubber Manufacturers.*—In this trade indiarubber in bulk is dissolved in mineral spirit, and then mixed up with other ingredients to form a plastic substance, which is worked up into various forms of indiarubber goods.

I think the arrangements for the storage of the naphtha and for dissolving the rubber are probably adequate at all the premises under the Council's licence. After being taken out of the vessels in which

it is dissolved the indiarubber is of the consistency of dough, and it is so termed by the trade. It subsequently passes through a variety of machines, for manufacture into different articles, and during these processes some inflammable vapour is given off, but probably not in sufficient quantities to be liable to ignition. I recommend the Committee to in future attach a condition excluding fires and unsafe forms of artificial lighting, not only in the stores and mixing-rooms as at present, but also in any workroom where there is a liability to the presence of inflammable vapour.

(5) *Waterproof Garment Makers.*—This business is sometimes conducted on a very large scale in very large buildings, and in others on a small scale, and sometimes in dwellings. No matter how many or how few hands are at work, each of them requires a small quantity of solution and a small quantity of spirit. This is used for cementing the seams of the garments to be manufactured, and as there is but a small amount of vapour given off in the operations of each workperson, it is only where a large number of workpeople are employed in one room that there is a liability to the formation of a large amount of inflammable vapour. The two points for the consideration of the Committee appear to be:

(1) Whether fires and exposed artificial light should not be prohibited in all such workrooms.

(2) Whether facilities for escape, in case of accident, should not be insisted upon, wherever a considerable number of hands are employed in one building.

By requiring both the solution and the naphtha to be used from suitable vessels, and by regulating the storage of the naphtha and the mixing of the solution, the Council has reduced the danger in these places; but the other points indicated are matters for serious consideration. I may point out, however, that there might be great difficulty in the case of the smaller makers, and of the workpeople who carry on this business in their own homes, in providing a special artificial light, or special means of heating the rooms.

(6) *Glass Silverers.*—In this business mineral spirit is used in the manufacture of the paint which covers the back of silvered glass. The spirit is usually kept and the paint mixed in the basement of the building where the business is carried on, and it has been impracticable to obtain in such cases external places for the storage and the mixing. There is probably little danger in the process of applying the paint to the glass; and the point for the consideration of the Committee appears to be whether in future the storage and mixing should be allowed in the building in which the workrooms are situated.

(7) *Glove Cleaning.*—In this business only small quantities of

mineral spirit are used, and in a large number of cases the trade is so small that it can be carried on under the exemption contained in section 7 of the Petroleum Act, 1871, which permits three gallons of spirit to be kept without a licence, provided it is kept in stoppered bottles which contain not more than one pint. The practice in London is that, where only one of these bottles is open at a time, no licence is necessary, but whenever any larger quantity than one pint is opened for use at one time a licence is requisite. Although the quantity of petroleum used in glove cleaning is small, there is a considerable escape of inflammable vapour, and consequent danger. Upon every premises licensed by the Council, glove cleaning is required to be carried on in buildings either detached or external to the house or shop, and the presence of a fire or artificial light is forbidden. It is probably unnecessary to add to the restrictions already imposed on this business.

In addition to the foregoing, there are also a few other businesses in which petroleum spirit is used, and which are under the licence of the Council, as follows:

One bone boiler.
,, bedstead manufacturer.
,, photographic chemical manufacturer.
,, manufacturing chemist.
,, brassfitter (asbestos packing).
,, paraffin scale maker.
,, electrician (four licences).
,, colour-printing works.

I believe the conditions imposed in each of the above cases are adequate for safety.

The only remaining trade in which it is known that petroleum spirit is used is that of toy-balloon maker. Two premises upon which this trade is carried on are licensed, and at each five gallons may be kept. In both cases the store is a sunk pit in the garden at rear of the dwelling, and this method is quite safe. The spirit is, however, taken in quantities not exceeding half a gallon into a workroom in the upper part of the dwelling, where it is put into an open vessel, into which the indiarubber is dipped. No fire or light is allowed in this room, and the work is done with open windows, and it is probable that no further precaution can be adopted except to require that the work be done in outbuildings only. The licensees are, however, so poor that they are unable to provide these. These premises have been under licence for some years, and the inspector reports that he has always found the business conducted with care.

APPENDIX XVI.

SCALE OF MAXIMUM AMOUNTS OF PETROLEUM ALLOWED TO BE KEPT ACCORDING TO DISTANCE FROM PROTECTED WORKS.*

(Proposed to be included in an Act of Parliament.)

Distance of depot from protected work.*	Number of gallons allowed to be kept		
	Not wholly in tank-depots.†	In tank-depots† but not wholly underground.	Wholly in underground tank-depots.†
Within 10 ft.	100	250	500
Over 10 ft. and not exceeding 20 ft.	500	1,500	5,000
" 20 " " " 30 "	2,000	6,000	20,000
" 30 " " " 50 "	5,000	15,000	50,000
" 50 " " " 75 "	10,000	50,000	Unlimited.
" 75 " " " 100 "	15,000	150,000	—
" 100 " " " 150 "	20,000	Unlimited.	—
" 150 "	Unlimited.	—	—

* For definition of protected works, see p. 164.
† Specifications of tank-depots will be found in Appendix X.

T

INDEX.

Abel, Sir F., report on testing, 81, 136, 137; his report of 1876 on testing petroleum, 82–85, 140; experiments by (with Dr. Redwood), on flash-points at different altitudes, 91; and in tropical climates, 91

Abel test, 69, 70, 71; legalisation of, 85; mode of using, 85–89

Abel-Pensky test, 93–104

Abergele, fire on goods train at, 167

Acetone, its capacity for absorbing acetylene, 197

Acetylene, prepared from carbide by Maquenne and by Willson, 9; carbides which yield, 10; quantity yielded by calcium carbide, 194; explosive compressed, prohibited, 196, 197, 278–280; non-explosive kinds permitted, 196, 197, 281; absorption of, by acetone, 197; explosive mixtures with air prohibited from distribution, 197, 198; uses of, 199; London County Council's regulations respecting, 243–246; Orders in Council relating to, 278–280; Orders of Secretary of State as to, 281–283

Act of 1862, 134–135; of 1868, 137–138; of 1871, 138–139, 149 *et seq.*, 204–221, 274–275; of 1879, 140–141, 149 *et seq.*, 221–227, of 1881, 151 *et seq.*, 232–234

Aichungs-Kommission, standardisation of testing instruments by, 101–104

Alabama, petroleum yield of, 31–32

Alaska, occurrence of oil in, 31

Alfreton, petroleum at, 7

Anticlines favourable for accumulatiou of petroleum, 25–26

Appalachian oil-field, yield of, 31, 32

Apscheron peninsula, petroleum yield of, 34

Arnaboldi open-test apparatus, 79

Asphalt; in Trinidad, 6; Peckham's view as to, 12

Asphaltum, 4

Assam, oil supply of, 31, 37

Astatki, 30, 58, 59

Athabasca, occurrence of oil in, 31

Atmosphere of tanks and other spaces, modes of testing, 117–124

Atmospheric pressure, disturbing influence of, in testing the flash-point, 90, 91; table of correction of apparent flash-point for varying, 100, 264

Attfield, Prof., report on testing, 81, 136, 137

Auger, 41, 42; dressing the bit, 44

Bacon on the origin of petroleum, 7, 8

Bailer, 42, 49

Baku, petroleum at, 5, 28, 33, 34

Balakhany, petroleum production of, 34

Barbados tar, 6

Barque *A. Goudey*, petroleum explosion on, 158

Barrels for carrying oil, 46; danger from empty petroleum barrels, 161

Beilby on the flash-point, 71, 72

Benzene, 61, 63, 66

Benzine, 58, 59, 63

Benzine Collas, 67

Benzol, 61, 66

Benzoline, 57, 63

Bergmann on bitumen, 8

Bergöl, 3

Berthelot, his views as to the origin of petroleum, 9
Bibi-Eibat, petroleum production of, 34
Bill of 1869, 138 ; of 1872, 139 ; of 1883, 141–142 ; of 1891, 143 ; introduced by Mr. Reckitt, 146–147
Binagadi, petroleum production of, 34
Bits. See *Auger*.
Bitumen, 4 ; use of, as mortar, 5 ; Macquer's account of, 8 ; Bergmann and Hatchett's views as to, 8 ; Peckham's view as to, 12 ; probable plant origin of the Trinidad deposit, 18, 19 ; distribution of, 22–24
Boiling-point, use of, in testing, 130
Borneo, petroleum production in, 31, 37
Boulevard gas oil, 56, 63
Bradford, ignition of petroleum vapour by electric spark at, 160
Brea, 4
Bristol, fire at, 163, 164
Brown coal, 60
Bull rope, 40
Bull wheel, 40
Bunte, Dr., on the use of a stirrer in the Abel test, 88
Burma, petroleum production in, 31, 37
Burma crude petroleum, mode of testing, 93
Burmah oil, 1, 2
Burners of petroleum oil lamps, good and bad points of, 175, 176
Burning naphtha, 66, 67
Burning oils, 60, 66
Byasson, his theory on the origin of petroleum, 10

CALDERWOOD, J., consulted as to test standard, 84
California, petroleum production of, 32, 33
Canada, petroleum production of, 31, 34, 35
Canadol, 63
Carbide, acetylene obtained from, by Maquenne and by Willson, 9
Carbide of calcium, Orders in Council as to, 151, 274–276 ; precautions applicable to, 193–196 ; uses of, 199 ; London County Council's regulations respecting, 243–246 ; model code of harbour by-laws respecting, 277
Carbides, Moissan's researches on, 9 ; Matthews's classification of, 9, 10 ; product of the action of water on, 10
Carbolic acid, 61
Carburine, 63
Carpathian oil-fields, 18
Casing the wells, 44, 45, 49
Chimney gallery of petroleum oil lamps, 176
Clamps, 42
Clay as an absorber of petroleum, 20
Close test, 77
Clowes, Prof. (with Dr. Redwood), petroleum-vapour test, 117 ; his miner's test lamp, 118
Coal tar, 60, 61, 62 ; products of, 61, 62, 66–67
Coleman *v.* Goldsmith, 140–141
Colombia, occurrence of petroleum in, 31
Colorado, petroleum production of, 32
Conductor, 43
Conveyance. See *Transportation*
Cosmoline, 65
Covers required for vessel containing petroleum, 161
Creosote oil, 61
Crown block, 39
Crystal oil, 64, 66
Cymogene, 56

DALTON, table of geographical distribution of bitumens, 23, 24
Danforth's oil, 63
Derrick, construction of, 39
Dewar, Prof., on the flash-point, 73
Distillation of petroleum by intermittent and continuous processes, 49, 50
Dolomite as oil reservoir, 26, 27
Doterel, explosion on H.M.S., due to paint driers, 162
Drill. See *Auger*
Drilling tools, 41–44
Drive pipe, 43
Dry cleaners, use of petroleum spirit by, 285

EARTH balsam, 4
Ecuador, petroleum occurrence in, 31
Electric light (incandescent and arc) dangers of, near petroleum spirit, 159
Electric spark, dangers of, near petroleum spirit, 159, 160

Elliott tester, 107–109
Elsass, petroleum production in, 31, 37
Engler, on the animal origin of petroleum, 12, 13; confirmatory experiments by, 13, 14, 19, 20; experiments on testing apparatus by Haas and, 87, 88; Haas and, on the Salleron-Urbain test, 115
Erdöl, 3
Ethylene produced by certain carbides when acted on by water, 10
Explosives Act, 1875, extended to acetylene gas by Orders in Council, 278–280; and by Order of the Secretary of State, 281–283

Filling hole of lamps, 174, 175
Fire, means of restricting damage by, 162 *et seq.*
Fire test, 75, 76
Fish oil, experiments by Engler on, as a possible source of petroleum, 13, 14
Fishing tools, 42, 43
Flame cap, 117–122
Flash-point, 3; explanation of term, 68, 69; conditions affecting, 69–75; standard for, 74–75; determination of standard, 84, 85; table for correction of observed, for variation in atmospheric pressure, 100, 264
Fossiline, 65
Foster tester, 112–114
Fractional distillation test for crude petroleum, 132
Fraser, W. J. & Co., their assistance in construction of petroleum-vapour test apparatus, 117
Frictional test for lubricating oils, 133
Fuel oil, 59

Galicia, petroleum from, 6, 31, 35, 36
Gas oil, 58, 59, 60, 65, 66; method of testing, 129
Gasoline, 56, 60, 63, 66
Generators, precautions as to safety of acetylene, 194, 195
Geoline, 65
Geological distribution of bitumens, 23–24
Germany, petroleum production of, 36, 37; adoption of the Abel-Pensky test in, 93–97
Glasgow, fire at Anderston Quay, 164
Glass-silverers, use of petroleum spirit by, 287
Glove-cleaning, use of petroleum spirit in, 287, 288
"Go-devil" clearing apparatus, 48
Gold Coast, petroleum occurrence on, 31
Granier tester, 110, 111
Gray's tester, 127–129
Great Russell Street, fire in, due to throwing a lighted match on spilt petroleum spirit, 168
Grozni, petroleum production of, 34

Haas, 87, 115
Hackney, fire at, due to uncovered petroleum oil, 161; and to a van catching fire in the street, 168
Hanover, petroleum yield of, 37
Harbour by-laws, 150, 153, 235–237, 277
Harburg, petroleum explosion at, 73, 158
Hatchett on bitumen, 8
Hawking, legality of, 140; Act regulating petroleum, 151, 152, 169, 232–234, 241–242
Headache post, 40
Helmet manufacturers, use of petroleum spirit by, 285–286
Heptane, 123
Höfer, on the animal origin of petroleum, 12, 13, 19
Hungary, petroleum occurrence in, 31
Hunt, S., on petroleum contents of porous rocks, 28
Hutchinson, the pioneer of pipe line transportation, 47
Hydrocarbons produced by the action of water on carbides, 10
Hydrogen flame-cap testing apparatus for petroleum vapour, Dr. Redwood's, 117–124

Illinois, petroleum production of, 32
Impervious rocks as preservers of petroleum deposits, 26
Indian Territory, petroleum production of, 32
Indiana, petroleum fields of, 25, 27, 32, 33
Indiarubber manufacturers, use of petroleum spirit by, 286–287
Indiarubber solution, 62; mode of testing, 89, 90
Inflammable Liquids Bill, 143–144

Iron carbide as a source of petroleum, 10, 11
Italy, petroleum production in, 31, 37

Japan, petroleum production in, 31, 37
Jars, 41, 42
Java, petroleum production in, 31, 37
Jerk-rope, 43

Kansas, petroleum production of, 32
Karabugas gulf, accumulation of organic remains in, 17
Karns, the suggestor of pipe line transportation, 47
Keates, T. W., consulted as to test standard, 84
Kellner, Dr., inquiry by, into petroleum testing, 83; on the influence of tropical climates on the flash-point, 92
Kentucky, petroleum yield of, 31, 32
Kerosene, artifically prepared by Engler, 13, 14; storage and distribution, 52–54; from American petroleum, 58, 64; from Russian petroleum, 58, 59, 64; use of, for lighting, 67; method of testing, 77 *et seq.*; specific gravity, 129

Lambeth, fire at, 161, 164
Lamps for petroleum oil, their construction, 171; selection of, 171, 172; oil container, 173, 174; relative dangers of different kinds of oil containers, 174; filling-hole, 174–175; burners, 175, 176; safety devices, 176, 177; suggestions for the care and use of, 272–273
Leakage, dangers from, 160, 161, 164, 165, 167, 168
Legislation relating to petroleum, 134–156; Act of 1862, 134; Select Committee of 1867, 135; report of the "three chemists," 136; Act of 1868, 137, 138; Bill of 1869, 138; Act of 1871, 138, 139; 204–221; 274–275; 277; Act of 1879, 140–141; 221–227; Act of 1881, 141; 232–234; Bill of 1883, 141–142; Bill of 1891, 143; Report of Committees of 1894 to 1898, 145–147; Petroleum Acts of 1871, 1879, and 1881, 148 *et seq.*; 235 *et seq.*; 247 *et seq.*;
Legislation—(*continued*) defects in existing, 152 *et seq.*; Order as to petroleum spirit for locomotives, 156; 265–267; relating to carbide of calcium, 191 *et seq.*; 243 *et seq.*; 276; and to acetylene, 196 *et seq.*; Explosives Act, 1875, extended to acetylene gas, 278 *et seq.*
Lesley, on the origin of petroleum, 11, 12; on the pressure in oil wells, 29
Lesquereux, on the vegetable origin of petroleum, 15
Letheby, Dr., on the flash-point, report on testing, 81, 136
Lewes, Prof., his work on acetylene, 199
Licence, forms of, 150, 151, 239, 247–260
Life preserver, 40
Lightning conductors required for petroleum tanks, 160
Ligroïne, 63
Lima-Indiana oil field, yield of, 31, 32
Limestone as oil reservoir, 26
Liquid fuel industry, 30, 67
Locomotives, Order as to petroleum spirit for, 156, 265–267
London, ports and storage arrangements of, for kerosene, 52–54
London County Council forms of licence, 150, 151; 247–256; regulations issued by, relative to petroleum, 238–256
Lubricating oils, 58, 59, 60, 65, 66; methods of testing, 124, 129, 130, 132, 133
Lyon, Dr., on the flash-point in India, 92

Macquer on bitumen, 8
Maltha, 4
Maquenne, acetylene prepared by, 9
Marine oil, 66
Matthews, classification of carbides, by, 9, 10
Mendeleeff, on the origin of petroleum, 10, 11
Metal tanks for petroleum, 162, 163
Methane produced by the action of water on certain carbides, 10
Mexborough, petroleum leakage and explosion accident at, 160
Mexico, petroleum occurrence in, 31

Meyer, V., on stirrer in oil cup, 87
Miano, oil from, 6
Mineral colza oil, 58, 64
Mineral jelly, 65
Mineral seal oil, 64
Mineral sperm oil, 64
Mineral spirit, method of testing, 129, 130
Mineral tar, 4
Missouri, petroleum production of, 32
Modena, petroleum of, 6
Moissan, on carbides, 9
Motorine, 63
Mountain ranges, association of, with petroleum deposits, 22-23

NAKED lights near petroleum, dangers of, 157, 158
Naphtha, 4, 56, 57, 60, 61, 63, 66
Naphthalene, 61
Naphthometer, Parrish's, 111–112
Newfoundland, petroleum occurrence in, 31
Newport, explosion at, due to leakage of petroleum, 160
New York, petroleum field of, 28, 32
New Zealand, petroleum occurrence in, 31
Notting Hill, fire at, 164

OCHSENIUS, on the animal origin of petroleum, 15
Ohio, petroleum of, 25, 27, 28, 31, 32, 33
Oil containers of lamps, good and bad points of, 173, 174
Oil fountains of Russia, 29
Oleum Médea, 4
Oliphant, on the petroleum industry of the United States, 31
Open test, 77
Open test apparatus of Petroleum Act, 1868, 80–82
Orton, on the origin of petroleum, 12, 20, 21; on oil content of porous rocks, 27, 28
Outflow of petroleum in fires, importance of preventing, 163, 164
Ozokerite, 65

PAINT driers, 62; dangers of using, 162
Paints, 62; mode of testing paints containing petroleum, 90
Paraffin, included in the legal definitions of petroleum, 1; separation of, from petroleum, 58, 60, 65; testing of, 133
Paraffin oil of Scotland, 7, 64, 66
Paraffin scale, 65
Paraffin wax, 65
Paraffinum liquidum, 65
Paraffinum molle, 65
Parrish's naphthometer, 111–112
Peat, 60
Peckham, on the origin of petroleum, 12; on the distribution of petroleum, 22, 23
Pedler, Dr., on the flash-point in India, 92
Pennsylvania, oil fields of, 28, 31, 32, 33
Pensky, his modification of Abel's test, 93–101
Pensky-Martens tester, 124–127
Pentane, 57, 63, 123
Persia, oil springs of, 6
Peru, petroleum production in, 31, 38
Petriana, explosion on the, 166
Petrol, 56, 57, 63
Petrolatum, 65
Petroleum, legal definition of, 1–3; commercial definition of, 3; origin of term, 3; synonyms for, 3, 4; Biblical references to, 4, 5; classical references to, 5; found in Barbados, and in other localities, 6; origin of, according to Bacon, 7, 8; Macquer, Bergmann, Hatchett, 8; Berthelot, 9; Byasson, 10; Mendeleeff, 10, 11; Sokoloff, 11; Lesley, 11, 12; Ashburner, Orton, Peckham, Strippelmann, 12; Höfer, 12, 13; Engler, 12–14; Zaloziecki, 14, 15; Ochsenius, 15; Lesquereux, 15; comparison of the theories, 15, 16; discussion on the organic origin of, 16–21; geological and geographical distribution, 22–38; transportation of, 46–48; 51, 52; refining, 49–51; physical properties of crude, 55; chemical composition of, 55, 56; commercial products of, 56–67; fractional distillation test for crude, 132; legislation referring to, 134–156; 232 *et seq.*; precautions necessary for, 157–170; storage quantity allowed, 164; imports of, into the United Kingdom for 1899 and 1900, 200–202; regulations as to use of, for locomotives on highways, 265–267; businesses licensed to use, 284–288
Petroleum distillate, 3, 50, 51

Petroleum ether, 56, 57, 63
Petroleum (Hawkers) Act, 1881, 151–152, 232–234
Petroleum oil, 3, 64; precautions necessary in using, 157 *et seq.*
Petroleum spirit, 63; Captain Thomson's pressure test for, 130, 131; precautions necessary in using, 157 *et seq.*, 284–288; imports of into the United Kingdom during 1899, 1900, 202, 203; conveyance of, 241; regulations as to use of, for locomotives on highways, 265–267
Petroleum wells, methods of sinking, in the United States, 39–45; in Russia, 48, 49
Petrolina, 65
Petroline, 66
Photogene, 64
Pieler, his hydrogen flame test lamp for mine air, 117, 118
Pipe line transportation of oil, 47; pipes used for trunk lines, 47, 48
Pissasphaltum, 4
Pisselæum, 4
Pitch, 62
Pitchford, bitumen at, 6, 7
Pitman, 40
Porous rocks as reservoirs for petroleum, 26, 27, 28
Precautions as to use of petroleum, 157–170
Pressure in oil and gas wells, 28, 29
Pressure test for petroleum spirit, Captain Thomson's, 130, 131
Pumping engines, 48
Pumping from wells, 45
Pyrometer, Tagliabue's, 104–107
Pyronaphtha, 64

Quebec, petroleum occurrence in, 31

Railway transportation of oil, 46, 47, 153, 154
Rangoon oil, 1, 2, 37
Reamers, 41
Receiving tanks, 45, 46, 48
Reckitt, Mr., Bill introduced by, 146–147
Redwood, Dr., experiments by, at different altitudes and in tropical climates, 91; on testing the air of confined spaces for petroleum vapour, 117 *et seq.*; his standard viscometer, 133
Redwood, R., his assistance in devising vapour-test, 117
Redwood, T. H. (with Dr. Redwood), photographs of flame-caps, 122
Refined oil, 58
Refining petroleum, 49–51; 64
Regent's Park Canal, explosion on, 165, 168
Rhadinance, 5
Rhigolene, 56
Rods used in drilling petroleum wells, 49
Romany, petroleum production of, 34
Roumania, petroleum production of, 31, 35, 36
Russia, petroleum production of, 30, 31, 33–34; method of sinking wells in, 49

Sabuntchi, petroleum yield of, 34
Safety devices for petroleum oil lamps, 176, 177
St. Quirinus's oil, 4, 6
Salleron-Urbain tester, 114, 116
Salt, 5
Samson post, 39
Sand as an extinguisher of fires caused by petroleum, 162
Sand pump, 42
Sand reel, 40
Sandstones as oil reservoirs, 26
Saxoline, 65
Saybolt's electric tester, 79, 80
Scotland, shale output of, 37; shale oil industry of, 51, 60
Screen walls, specification of, 268–271
Seneca oil, 4, 5
Shale oil, 66
Shale oil industry, 37, 51, 60
Shale spirit, 66
Shales as a covering for reservoir rocks, 27
Sharp oil, 66
Sicilian oil, 4, 5
Sinker bar, 41
Slime, 4
Sokoloff, on the origin of petroleum, 11
Solar oil, 58, 59, 64
Solar oil distillate, 64
Solvent naphtha, 66, 67
Sparks, protection of petroleum spirit from, 168
Specifications of tank depots and screen walls, 268–271
Specific gravity as a test of petroleum oils, 129–130
Spudding, 43

Squire's open test instrument, 78, 79
Stability, importance of, in a petroleum lamp, 172
Standardising testing apparatus, 101–104
Steam engine used in drilling petroleum wells, 40
Steinöl, 3
Steuart on the flash-point, 71
Storage of petroleum, precautions needed in, 164–165, 239–241
Storage tanks for kerosene, 53; for petroleum, 162, 163; mode of cleansing, 166, 167; specification of 268–270
Stripplemann, on petroleum, 12
Suffocation, danger of, when entering spaces charged with petroleum vapour, 169
Sumatra, petroleum production of, 31, 37

TAGLIABUE, open test instrument, 76, 77, 78; his coal oil pyrometer, 104–107
Tail house, 50–51
Tancarville, explosion on the, 123
Tank barges for transport of oil, 47
Tank steamers for transport of oil, 51, 52; precautions needed in, 165, 166
Tank wagons for carrying oil, 46, 47
Telegraph, 40, 41
Temper screw, 42
Tennessee, petroleum production of, 31, 32
Tennis shoe makers, use of petroleum by, 286
Terrace structure associated with petroleum deposits, 25
Test-tube method of testing flash-point, 116, 117
Testing, 77–133; 228–231
Texas, production of petroleum in, 31, 32
Thomson, Capt., his pressure test for petroleum spirit, 130–131
"Three chemists," report of the, 136
Todmorden, suffocation accident at, 169
Toluene, 61, 66
Torpedoing wells, 45
Toy balloon making, use of petroleum spirit in, 288
Transportation of petroleum, 46–48; 51, 52; precautions needed in, 165 *et seq.*
Trenton limestone as an oil reservoir, 26–28; 32
Trinidad, asphalt at, 6; probable plant origin of bitumen in, 18, 19
Tropical climate, effect of, on the flash-point, 91, 92, 93
Trunk lines, 47; pipes used for, 47, 48

UNITED States, petroleum production in, 30–33; methods of sinking petroleum wells in, 39–45; mode of raising and transporting the oil in, 45–49

VAN Syckle, his successful pipe-line, 47
Varnishes, 62
Vaseline, 58, 65
Ventilation of petroleum spirit stores, 162; of tank steamer holds, 166
Viscometer, Dr. Redwood's standard, 133
Viscosity test for lubricating oils, 132, 133

WALKER GATE, fire at, 163
Walking beam, 39
Wall, on Trinidad Pitch Lake, 18, 19
Warden, Dr., on the flash-point in India, 92
Water, products formed by its action on carbides, 10; of no use for extinguishing fires caused by petroleum, 162; or by calcium carbide, 193; dangers arising from contact of, with calcium carbide stores, 193, 194
Water-lime bed as an oil reservoir, 28
Waterproof garment makers, use of petroleum spirit by, 287
Water-white oil, 58; experiments with, 84, 85
West Indies, petroleum occurrence in, 31
West Virginia, petroleum yield of, 31, 32, 33
Westphal balance, 130
Wick-tube of petroleum oil lamps, 176
Winged substitute, 41, 42
Wisconsin tester, 107

Wrenches, 42
Wyoming, petroleum occurrence in, 32

XEROTINE Siccative, explosion of vapour from, 162
Xylene, 61

YENANGYAUNG, petroleum at, 6, 37

ZALOZIECKI, on the animal origin of petroleum, 14, 15
Zuber, on Carpathian petroleum, 18

Printed by BALLANTYNE, HANSON & Co.
London & Edinburgh

HARVARD ENGINEERING SCHOOL